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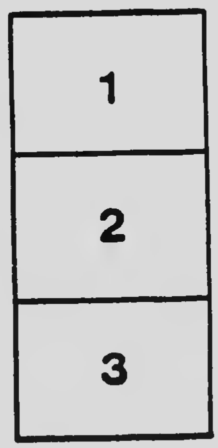
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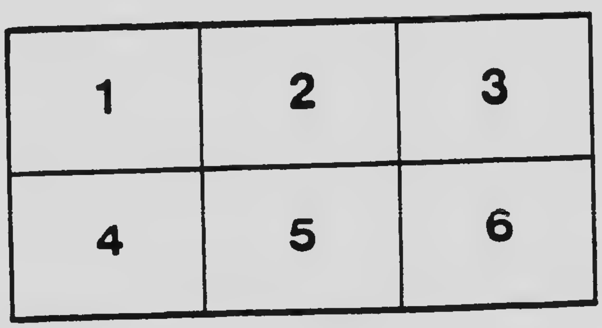
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CANADA
DEPARTMENT OF MINES
GEOLOGICAL SURVEY BRANCH
Hon. W. Templeman, Minister; A. P. Low, Deputy Minister;
R. W. Brock, Director.

MEMOIR No. 2

THE

GEOLOGY, AND ORE DEPOSITS

OF

HEDLEY MINING DISTRICT

BRITISH COLUMBIA

BY

CHARLES CAMSELL

OTTAWA
GOVERNMENT PRINTING BUREAU
910

No. 1093

Frontispiece. PLATE I

9185

Hedley, and the valley of Twentymile creek, B. C.

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No. 1093

LETTER OF TRANSMITTAL.

To R. W. Brock, Esq.

Director Geological Survey,

Department of Mines,

Sir,—I beg to submit the following memoir on the geology, and ore deposits of Hedley Mining District, with an appendix on the adjacent districts of Henry creek and Golden Zone.

I have the honour to be, sir,

Your obedient servant,

(Signed) Charles Camsell.

June, 1909.

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THE

GEOLOGY, AND ORE DEPOSITS

OF

HEDLEY MINING DISTRICT,

BRITISH COLUMBIA

BY

CHARLES CAMSELL.

CHAPTER I.

INTRODUCTION.

GENERAL STATEMENT.

The Hedley district is one which has proved to be of considerable interest to students of economic geology, on account of the unique character of the ore deposits, which apparently have no known parallel in North America; but to Canadians this scientific interest is supplemented by the importance of the region as a producer of gold. The object of the survey, herewith reported on, was to make a detailed geological study of the whole area, and to investigate the nature, occurrence, and probable extent of the ore bodies, so that some assistance might be rendered to future operators in the district, in the discovery and working of new ore bodies. The purely geological results have proved to be very interesting and satisfactory, and it is believed that something of interest has been added to the literature of economic geology. The object of the present report is to present in as complete a manner as possible, both the stratigraphical and economic results that have been obtained by this study. From the limited number and variety of ore deposits being developed, and the consequent necessity of drawing conclusions from only a few of such deposits, the chapter on economic geology is not as complete as it may be made at some time in the future, but it will be found to contain virtually all that is known of these deposits at the present time, and it is believed that much of the information contained herein will be found of some usefulness to prospectors and operators in the district. It is the opinion of the author that all the ore bodies that can be worked to a profit have not yet been discovered in this district, and it is only to be expected that when others become known, variations will be found in the nature and occurrence of these, which may necessitate some modification of the views and conclusions here expressed.

FIELD WORK AND ACKNOWLEDGMENTS.

The following report on Hedley is based on field work carried out in two successive seasons—in 1907, from May to September, and in 1908, from June to the end of August. The topographic survey of the camp was begun in May, 1907, and carried on throughout that season, mainly by Messrs. A. O. Hayes and J. A. Allan, under the writer's supervision. In 1908, about one-third of the map remained unfinished, and this work was undertaken and completed by Mr. Leopold Reinecke, assisted by Mr. S. A. Wookey.

Though the area covered by the map is not great, being only about 16 square miles, the time consumed in the topographic work was much longer than might seem adequate for a map of such size. This is accounted for by the physical conditions encountered in surveying, the ruggedness of the ground, and the inaccessibility of some of its parts.

The camp lies largely in the deep and narrow cañon of Twenty-mile creek, where it enters the Similkameen river. This cañon is from 2,500 to 4,000 feet deep, and its sides slope downward at angles of about 40°. These sides are gashed by many deep and narrow box cañons, so that it was impossible to get into many parts of the area, and others were reached only at considerable risk.

An accurately measured base line, 2,600 feet in length, was laid out in the valley of the river, and a triangulation from this formed the main control for the sheet. Transit and stadia traverses were run between triangulation points, and over all the wagon roads, tramways, and main trails. Between these traverse lines the detail was put in entirely by work with the plane-table and stadia, or by sketching and triangulation with the plane-table. All elevations are referred to mean sea-level, and were taken from a bench mark of the Canadian Pacific railway at the mouth of Twentymile creek. Mr. C. E. Cartwright, divisional engineer for that Company, kindly put all available data with regard to elevations at our disposal, and the necessary corrections were made.

In the geological work, able assistance was rendered by Mr. J. A. Allan, now assistant to Prof. T. A. Juggar in the Massachusetts Institute of Technology. The historical succession of the rocks, and the relation of these to the ore bodies, was studied and roughly marked out in the field season of 1907, and samples collected for petrographic study. This left, for the summer of 1908, the delineation of the geological boundaries on the map, and the completion of such other details relating to contact metamorphism and the ore bodies as were not worked out in 1907.

By August 20, the field work of Hedley was virtually completed, and the remaining portion of the field season was devoted to the examination of certain groups of claims adjoining the Hedley camp, with a view to determining what similarity, if any, there might be between ore bodies in different portions of the same district. It was found that, while in places the geological conditions were somewhat similar, yet as a rule the conditions under which ore bodies were found to occur were totally dissimilar—that is to say, the Hedley ores are to be considered as being unique, the area throughout which they occur is a restricted one, and they have no known counterpart in districts outside this area.

Development of the mineral claims of Camp Hedley has not yet reached an advanced stage, and indeed, serious mining operations have been carried on upon only two of these claims, the greatest depth reached being not more than 250 feet. It is not unreasonable to expect that with the further prospecting and development of other claims in the camp, new ore bodies will be discovered, and in the opinion of the writer, it would indeed be surprising if, as some suppose, the above-mentioned two claims contain all the ore of any economic importance in the whole camp. Under these circumstances, and with the probability of further development and discoveries, it would be presumptuous on the part of the writer to assume that this report contains the final word on the geology and ore deposits of the camp; and it is quite possible that when, in the future, a more detailed study is made of these rocks, and particularly of the ore bodies, these conclusions may be modified, or other conclusions arrived at. Nevertheless, the present report is presented, with the belief that in its main features it is correct, and will require no change, and that any changes that are found necessary at any future time, will only be of minor importance, and will not affect the value of the report as a whole.

While the geology of the camp is in many respects, rather complicated, the rocks themselves are, as a rule, well exposed, and only on the eastern portion of the sheet are they covered with much drift. Contacts between different types of rock were generally found by a little search, and this simplified to a great extent the working out of geological relations.

With regard to the ore bodies, it was unfortunate that so little work was being done on the great majority of the claims, as it was impossible, without the aid of the owners, to discover places where cuts had been made, or shafts sunk. To this is due, in a great measure, the lack of mention in this report of any claims outside of those owned by two companies and three or four individuals. Every effort, however was made by the people of Hedley to assist us in carrying out the work. The Yale Mining Co., and the Daly Reduction Co., through their officers, gave us unstinted support, and saved the party a great deal of time and hard work. The almost daily use of the gravity tram-line to ascend the 4,000 feet to the Nickel Plate mine, often when it was not convenient to carry passengers, was a very great convenience; free access to all the Sunnyside and Nickel Plate mine workings was accorded at all times, and it is principally from a study of the occurrence of the ore bodies on these two properties that deductions are drawn as to the origin and history of the ores of the whole camp.

In almost every case, the owners of claims who lived in Hedley were willing and eager to lend assistance in examining the ground in which they were interested: but in cases where owners could not be found, the examination of their claims had to be made alone, and much of interest may have been missed. Altogether, we have to thank the people of Camp Hedley for generous assistance.

In the petrographic study of the rocks and ores, and in the other work incident to the compilation of this report, the writer is pleased to acknowledge the generous assistance and advice rendered by all the members of the geological department of the Massachusetts Institute of Technology. To Prof. C. H. Warren, in partic[illegible]r, are acknowledgments due for much assistance in the petrograph[illegible] study of the different rock species met with, and of the ores; to [illegible]f. R. A. Daly, also, for many helpful suggestions in the discuss[illegible]n of magmatic problems.

SITUATION AND MEANS OF COMMUNICATION.

Camp Hedley is to-day the most important mining camp in the whole Similkameen district of southern British Columbia, and con-tains one of the largest gold mines in Canada [illegible] p[illegible]ed [illegible] Osoyoos Mining division, and lies on the S[illegible]n river, the mouth of Twentymile creek, about 20 [illegible]rth [illegible] International Boundary line, and the same d[illegible]vest of the [O]kanagan valley. In extent the mining locatio[illegible] [c]amp cover not more than 16 square miles, and aggregate [illegible] virtually all of which are surveyed and Crown [illegible]

When the first mining claims were located [illegible] camp [illegible] only means of access from the outside world wa[illegible] the [illegible] ney trail, which followed the valley of the Sim[illegible]een [illegible] ning from Hope, on the Fraser river, throug[illegible] to the [illegible] country. This trail, built in 1860 by Moberl[illegible] and D[illegible] been used for many years, first by the Hud[so]n's Bay [illegible] traders, and later by prospectors, ranchers, and [ot]her [illegible] no thought was ever entertained by any of th[illegible] of the [illegible] in the mountain at the mouth of Twent[illegible] cre[e]k. [illegible] Nickel Plate mine began to show evidence [illegible]ecom[illegible] pro-ducer of gold, wagon-roads were built from [P]entictor [illegible] lake, both to the mine on top of the mount[ai]n, and t[illegible] of Hedley, where the re[du]ction works are situated. The [illegible] the mine to Penticton is only 28 miles by this road. [illegible] ch-inery, equipment, and supplies had to be transpo[r]ted [illegible] and much is still brought in this way. From Hedley [illegible] Penticton is 56 miles by the road which follows the Similkameen [va]lley, and until the winter of 1907-8, this was the easiest and most convenient means of entry. The Great Northern Railway Company has recently completed a branch line into Keremeos, which is only 20 miles from Hedley, and probably this will soon be extended farther up the river to the latter point. Surveys have been made for the exten-sion of this railway line through the Hope mountains to the Pacific coast, so that it will not be long before Hedley will be one of the stations of a transcontinental line. The country on both sides of the Similkameen valley is to a very large extent still unexplored, and is accessible only by means of a few hunting and prospecting trails, known only to the natives and a few of the older prospectors.

HISTORY OF DEVELOPMENT.

Unlike the majority of mining camps, or even some others in the Similkameen and adjoining districts, the history of Camp Hedley has not been eventful. At no time in the ten or twelve years of its existence has it been troubled with a boom; a feature so characteristic of many modern mining camps, and, as a rule, so detrimental to the best interests of the mining industry.

In the years immediately following the discovery of the rich placers of the Cariboo district in 1859, great crowds of prospectors and miners from the California gold fields took their way north by various routes. The principal route followed by these gold seekers was by sea to Victoria, and thence up the Fraser river to the gold fields. An alternative route followed by many was up the Columbia and Okanagan rivers, passing by the mouth of the Similkameen river, and thence overland by Kamloops and the Cariboo trail. Some of the overflow and stragglers, from the latter route, branched off the main route toward the west, and followed the valley of the Similkameen river, prospecting as they went. The gravels of this stream, and some of its tributaries, were found to carry the metal they were in search of, and pay varying in amount from $4 to $20 a day per man was struck on the bars and benches.

Placer mining of the gravels in the vicinity of the mouth of Twentymile creek was prosecuted in the early sixties, but this class of mining is always of a temporary character; and the exhaustion of the pay gravel is a matter of a very short time, after which the place is deserted. This, the first period in the mining history of Hedley, is relatively unimportant. It was of short duration, and is now almost entirely forgotten.

Following the logical sequence, the period of placer mining was only the antecedent of the more important and lasting period of lode mining. This period, beginning from the time that the first mineral claims were staked in the year 1896, has been one of slow but successful industrial development, until to-day the camp ranks as the most important in the whole Similkameen district: contains the largest gold mine in all Canada, and gives promise of still greater development when transportation is improved and mining facilities cheapened.

The first record of a mineral claim in Camp Hedley was in 1894, when C. Allison and J. Reardon staked three claims for the Hon. E. Dewdney and others, on ground that is now covered by the Climax, Windfall, Winchester, Lookout, and part of the Nickel Plate mineral claims. Mr. Coulthard also had a claim on what is now the Kingston mineral claim. These four claims were recorded at Granite creek, but they were not considered worth the annual assessment duty and were allowed to lapse.

In 1897, Peter Scott located the Rollo claim, and in the following year, after doing the necessary assessment work on this claim, he located the Princeton, Warhorse, and King. The Mound and Copper Cleft were staked about the same time by two Swedes, and in August of this year, Wollaston and Arundel located the Horsefly, Sunnyside, Nickel Plate, and Copperfield. Colours could be obtained by panning the red dirt in many of these prospects, and the unoxidized arsenical ore was in places exposed, but the owners did not yet thoroughly realize the value of their discoveries. Samples of the surface ore from the Nickel Plate were taken by Wollaston and Arundel to the Provincial Fair at New Westminster and exhibited there. It was here that Mr. M. K. Rodgers, who is more directly connected with the history and development of the camp than any other person, first saw the ore. He was travelling through the country in the interests of the late Marcus Daly, and was so impressed by the appearance of the ore samples that he immediately started on a trip to the Nickel Plate to make a closer examination and obtain samples. At that time there were no wagon roads in the country, and it took several days of arduous travel by rail, stage, and on horseback, to reach the district from the Pacific coast. The examination proved satisfactory to Mr. Rodgers, and a bond was taken, in November, on the four claims, Nickel Plate, Bulldog, Sunnyside, and Copperfield. Permanent work on these claims was started in January, 1899, and within a year the bond was taken up by Mr. Rodgers, and the balance of the purchase money paid to Wollaston and Arundel. The claims became the property of Marcus Daly, and since then development work has been continuous.

For over two years Mr. Rodgers confined all his attention to the preliminary development of the claims, and did not, as so many do, assume that he had a mine before the ground had been thoroughly prospected by tunnels, drifts, and surface cuts. In the meantime, a wagon road had been built from the Nickel Plate to Penticton, and supplies and machinery were brought in by this route.

In October, 1902, the properties having been thoroughly prospected, and proved to be worthy the expenditure of more money, the construction of a tramway to transport the ore from the mine to the valley of the Similkameen river was begun. The erection of a stamp mill and cyanide plant was also commenced, together with a flume 3 miles in length, to bring water for power purposes from Twentymile creek to the mill. These works were completed in May, 1904, and the milling of ore began.

In the meantime, other claims had been taken up, companies formed, and development work undertaken; but no actual shipments have yet been made, nor has any of the ore been treated by anyone outside the Daly Reduction Company.

The Great Northern railway now being built up the Similkameen valley to Hedley, will probably be the means of renewing interest in the camp, and stimulating claim owners to more thorough prospecting of their claims.

The town of Hedley, named after R. R. Hedley, formerly manager of the Hall Mines smelter at Nelson, B.C., was surveyed and laid out into lots in 1900. The town is built on the dry gravel bed to Twentymile creek, but is protected from floods by a strong embankment built to confine the stream to a restricted channel. Electric light is supplied from the power plant of the Daly Reduction Company, and a system of waterworks has been installed. Including the men employed in the mines, the population of the town is in the neighbourhood of 250 persons.

PREVIOUS WORK AND LITERATURE.

The literature of previous work in Hedley is neither long nor varied. While the town itself only dates from the year 1900, the first recorded mention of the rocks is found in the Report of Progress of the Geological Survey for 1877-78, by G. M. Dawson. What is now known as the Nickel Plate mountain was referred to then by Dawson as the Striped mountain, a name suggested by the distinctly banded appearance of the outcropping edges of the beds exposed, overlooking the Similkameen river. This Striped mountain is the hill on the east side of Twentymile, and not as some suppose that on the west side. Both are striped and the name might refer to either. While Dr. Dawson rightly attributes the banded appearance to the alternation of dark and light siliceous and argillaceous bands, this is only in a measure true, for the intrusion between the bedding planes of sheets of igneous rock which weather to a rusty brown has accentuated this feature, and contributed more to the banded appearance than the mere alternation of dark and light sedimentary beds.

Dawson also mentions the vicinity of Twentymile creek as one of the earliest places at which placer gold was mined in British Columbia.

During the years 1859, 1860, and 1861, the International Boundary commission was engaged in delineating the line of the 49th parallel, and Mr. Bauerman was connected with this commission as British geologist. His notes on the geology of the Similkameen river, as well as the rest of the mountain section, were compiled by G. M. Dawson and published as a part of the Geological Survey report for the years 1882-3-4. Bauerman followed the old trail which leads directly past the place where the town of Hedley now stands, and he makes mention of the very striking character of the rocks there exposed.

The Annual Reports of the Minister of Mines for British Columbia, from the year 1898 up to the present, contain references to the Nickel Plate mine and Camp Hedley. The majority of these simply contain a statement of the amount of work done annually, without any reference to the geology or the mode of occurrence of the ore bodies. In 1901, however, a visit was paid to the camp by Mr. W. F. Robertson, Provincial Mineralogist, and the annual report for that year is interesting as containing the first official and reliable account of the conditions obtaining here. In the report for the year 1905, there will also be found a detailed account, by a reliable authority, of the mill and methods used by the Daly Reduction Company in the extraction of the gold from some of the ores of Camp Hedley.

After the discovery of the Nickel Plate mine, and up to the present time, Hedley has been visited by many mining engineers, and some geologists, who were attracted thither by the unique character and peculiarities of the ore bodies. Little, however, has been written for publication by any of these men.

Three articles in popular style, by H. F. Evans, were published in the *Mining World*, of Chicago, but as the examination of the geology and ore deposits by this gentleman was confessedly hurried, some of the statements have not been borne out by our more extended survey.

A paper by R. A. Daly, in Vol. 17 of the Geological Society of America, entitled 'The Okanagan Composite Batholith of the Cascade Mountain System,' contains much interesting information on the history and method of intrusion of the igneous rocks of the 49th parallel. The distance from Hedley is only about 25 miles, and much that Dr. Daly has written has a bearing on the igneous history of the Hedley district.

For a general history of geologic and physiographic events in the Cordillera of British Columbia no better synopsis can be found than that of G. M. Dawson, given as the presidential address to the Geological Society of America, in the year 1901.

Besides these, which have a more immediate connexion with the geology of the Hedley district, some bulletins and professional papers by Smith, Willis, Russell, and Calkins on the geology of the State of Washington, and published by the United States Geological Survey, contain much that has a bearing on events on the Canadian side of the International Boundary line.

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CHAPTER II.

SUMMARY AND CONCLUSIONS.

GENERAL GEOLOGY.

The oldest rocks of the Hedley district are sedimentary rocks. These all belong to one conformable series, and have been referred to the Cache Creek group of Dawson's classification. No determinable fossils have been found in them, and their correlation with the Cache Creek rocks of the Kamloops map-sheet to the north has been made purely from lithological evidence. Until further paleontological evidence is obtained, they are called Carboniferous in age.

These rocks comprise a total thickness of at least 6,300 feet. This estimate is a minimum one, and covers only those rocks found within the limits of the map. Sedimentary rocks lying conformably above these, cover a large area outside the map, to the west, and may represent a continuous series extending through Carboniferous into Triassic times.

The sedimentary rocks of the district have been divided for convenience into four formations, the division lines of which are taken arbitrarily at some well-defined horizon. The lowest of these is the Redtop formation, consisting of massive limestone, cut off by intrusive granodiorite at the base, above which is a series of interbanded limestones, quartzites, and siliceous argillites, with some volcanic tuffs and breccias. Above this is the Nickel Plate formation, which is made up of massive limestone beds at the top and bottom, with interbedded impure limestones and quartzites between. Overlying the Nickel Plate formation is the Red Mountain formation, which is essentially volcanic and consists of andesitic tuffs and breccias of varying coarseness. The Aberdeen formation lies at the top of the whole series, and is represented by thin bedded limestones, quartzites, argillites, and volcanic materials.

Sedimentation was terminated by uplift of the whole region, whereby the rocks were elevated into a broad anticline, the crest of which lies over Eighteenmile creek, its axis running north and south. Dips in the centre of this arch are low, becoming almost vertical toward the west in the Aberdeen rocks.

Immediately following this uplift, or coincident with it, batholithic intrusion of igneous rocks began. Masses of diorite and gabbro were first intruded in the form of stocks, dikes, and sheets, and highly metamorphosed the older sedimentary rocks, forming at the same time the primary ore deposits. This took place some time during the Mesozoic period and was accompanied and followed by considerable faulting.

During Tertiary times, a second period of batholithic intrusion was instituted by the eruption of granodiorite on an enormous scale. Consequently, when this was finished, the Carboniferous rocks of the Hedley district were cut off on almost all sides by igneous rocks, and now remain only as a large roof pendant in the batholithic mass. This eruption was accompanied by considerably less contact metamorphism of the sedimentary rocks in the Hedley district than the previous eruptions, and apparently by little mineralization.

Erosion has sculptured the rock masses of the Hedley district since the uplift following the Carboniferous sedimentation, and the amount of waste has been enormous. Renewed power of erosion was obtained by uplifts both in post-Laramie and in Pliocene times. To the erosion period following the post-Laramie uplift is due the uniformity of level of the upper surfaces of the region, while the cañoning of the deep valleys is attributed to the post-Pliocene erosion period. It has been estimated that the uplift during this last period was at least 2,500 feet.

Although the whole district was covered by ice during the glacial period, the action of this on the upper surface levels is not marked. The erosion here was slight, and the chief evidence of occupancy by ice is the thin mantle of glacial debris, and the boulder erratics. In the main valley, however, there is much evidence of concentrated action, indicating that the valley was occupied by a glacier long after the upper levels were virtually free, its concentration in the valley being accompanied by greater velocity of movement, resulting in the scouring out of many hundreds of feet of material from the bottom of the Similkameen valley, giving the characteristic U shape now seen.

The final act in the creative history of the district was the deposition of thick deposits of washed gravels in the main valley, by waters overladen with glacial material derived from the vanishing glaciers of the Cascade mountains. These again are being destroyed, terraced, or carried away by the action of the streams.

ORE DEPOSITS.

Up to the present time, gold has been the only product of the mines of the Hedley district, and only two mines, namely, the Sunnyside and the Nickel Plate, are producing. The ore deposits were first discovered in the year 1896, but in the years immediately following, their development was slow, on account of the distance from established lines of communication, and the lack of any road better than a mere pack trail. After the entrance of the Yale Mining Company, however, in the year 1899, progress was more rapid, and this Company, after spending a great deal of time and money in demonstrating the value of their properties, building wagon roads and tramways, and opening up the country, delivered the first ton of ore to be treated in the stamp-mill, in the spring of 1904. Since then, operations have been continuous, save in exceptional years when the severity of the winter necessitated the closing down of the mill for a short time. The total tonnage of ore treated since 1904, up to the close of 1908, was 153,013 tons. From this, over $2,250,000 worth of gold has been obtained, at approximately $15 to the ton.

The formation of the primary ores of the district dates back to the intrusion of the gabbro-diorite rocks. This event is the first in the intrusive igneous history of the region, and is referred to a part of the Mesozoic period, some time after the deposition of the Carboniferous sediments. The intrusion of the diorite and gabbro rocks was exceedingly important, and as they were introduced very widely into the overlying sedimentary rocks in the form of stocks, dikes, and sheets, they exerted a strong and widespread influence on them. Wherever the gabbro-diorite rocks are in contact with these sedimentary rocks, extensive contact-metamorphism is apparent, resulting in the development of large masses of garnet, epidote, and diopside. The alteration is greatest where the igneous rocks are most abundantly intruded into the sediments, that is to say, within a radius of 1 mile from Climax bluff, which is about the centre of the contact metamorphic zone. The whole series of sedimentary rocks is more or less affected by these igneous intrusions, but in some the alteration is more extreme than in others. Quartzites, argillites, and volcanic tuffs have suffered relatively little. The massive limestone beds have suffered more, resulting in the crystallization of calcite, or more rarely in the metasomatic development of some of the lime silicates, particularly garnet and diopside. The most intense alteration has been in the impure limestone beds of the middle portion of the Nickel Plate formation, where the beds are not thick, and are interstratified with some quartzite strata. The result here has been the complete elimination of the carbonates, and a replacement by silicates, so that the rock is now a mass of garnet, epidote, diopside, and quartz, with occasionally some axinite. This metamorphism appears not only on the main contacts of diorite and gabbro, but also on the dozens of apophyses, large and small, which have been given off from the stocks. Most of these apophyses outcrop on the eastern side of the Nickel Plate mountain, as well as on the south, and are exposed there because of the uniform dip of the strata to the westward into the stocks of gabbro and diorite, which lie on the western slope of the mountain.

Wherever contact metamorphism has been effected in the sedimentary rocks, more or less mineralization has accompanied it. Like the contact metamorphism, mineralization has not been marked on the granodiorite contacts. It is much more notable on the diorite contacts, and greatest of all, on contacts of gabbro. The result of this mineralization has been the formation of arsenopyrite, pyrrhotite, chalcopyrite, pyrite, and sphalerite, and these minerals accompany the lime silicate minerals in such a way that their contact-metamorphic origin appears beyond a doubt. The origin of these ores is believed to be due to the emanations of water and metallic substances originally contained in the igneous magma, but released from it by a decrease of pressure on its reaching higher levels in the earth's crust. The deposits are, therefore, of contact metamorphic origin, and contemporaneous with the intrusion of the rocks of the gabbro-diorite complex.

The gabbro-diorite complex is made up of two main types of rocks, of which gabbro is the basic type. This rock is also very slightly younger in age. All the known ore bodies of the district are associated with intrusions of the gabbro, and it appears clear that this phase of the complex is genetically connected with the origin of the ores.

The ore deposits are irregular in outline, and with ill-defined boundaries on all sides but the foot-wall. This foot-wall is generally the gabbro intrusive sheet that has been responsible for the metamorphism and mineralization. On all other boundaries the values in the ore body gradually fade out into low-grade rock. The strike of the ore bodies on the Sunnyside and Nickel Plate mines is generally about N 70° W, and the dip is rarely more than 30°, and is dependent on the dip of the gabbro intrusive, which forms the foot-wall. The ore bodies have no apparent connexion with fissures, and are not always governed by the stratification of the sedimentary rocks.

From analysis of the different sulphides occurring in the ore bodies, it was found, that while all have some gold, as well as a little silver, the highest values lie in the arsenopyrite. While all the workable ore bodies must contain arsenopyrite, and the richest ore bodies carry more arsenopyrite than the poorer, it is certain that much arsenopyrite occurs throughout the district, that carries little or no gold. When, however, arsenopyrite occurs in the metamorphosed limestones on a gabbro contact, some values in gold are always found. The nature of the association of gold with the arsenopyrite has not been ascertained. On the surface, much of it was found free, and in quantities visible to the eye, but below the zone of oxidation the association with the arsenopyrite is much more intimate, and little of the gold is seen. It is believed that in the lower portions of the ore body the gold occurs either sparingly disseminated in the cleavage planes of the arsenopyrite, or else it is in actual solid solution in this mineral.

The zone of oxidation in this region is very shallow, never more than a few feet in depth. Secondary enrichment has, however, apparently taken place, below the zone of oxidation, by descending meteoric waters. It has been found that in ore bodies having a low angle of dip, there is a concentration of values on the foot-wall. The gabbro foot-wall is a dense close-grained rock, and relatively impervious to solutions, but even this is often enriched for a few inches on its upper surface by gold values. In the case of the Nickel Plate ore body, which lies on a gabbro foot-wall, and has a pitch of about 25° W, an impervious trough has been formed by the conjunction of the gabbro with a cross-cutting dike of so-called quartz porphyry; and in this trough a concentration of values has taken place at a depth of about 200 feet below the surface.

A careful study of the nature and occurrence of the ores can, in the opinion of the writer, lead to only one conclusion as to genesis. Contact metamorphism by the intrusion of igneous rocks into limestones, during which the primary ores were formed, followed by secondary enrichment by descending meteoric waters, will satisfactorily explain every occurrence of workable ore in the district.

The association of the ore bodies with the rocks of the gabbro-diorite complex, and particularly with the gabbro phase, is well proven. To this intrusion it is believed the ores are primarily due. It is believed that the contact metamorphism, whereby the calcareous sedimentary rocks were changed to a mass of lime silicate minerals, was due to the heat of the molten magma thrust into them. This metamorphism was aided to a very large extent by the action of water and other materials, which were given off by the molten magma and transferred to the intruded rocks. That there was a transfer of material is shown by the presence of substances—particularly arsenopyrite and axinite—in the contact metamorphic zone, which are not native to the sedimentary rocks, and are not found elsewhere in them. These substances, therefore, could only have been derived from the gabbro magma. Among these substances are iron, zinc, copper, arsenic, sulphur, boron, and silica. Gold, also, is believed to have been present in the magma, for assays of the gabbro generally reveal traces of gold. The intimate association, also, of gold with arsenopyrite denotes a common origin for both.

This gabbro magma, which gives evidence of having had a considerable amount of superheat, or of containing substances which greatly reduced its viscosity, carrying the above-mentioned substances in solution, forced its way upward through the overlying sedimentary rocks. As it reached the higher levels, the pressure gradually diminished, and the dissolved substances, including the gold, were released and passed off into the adjoining rocks, there to assist in the work of contact metamorphism, and to do the mineralizing. Those strata of limestone which were more porous and thin-bedded, and afforded the easiest and most numerous channels for the emanations, were the most highly altered, and received the greatest addition of material, while quartzites, argillites, and the more compact limestones suffered less. In this way, the primary ore deposits were found at and near the contact the gabbro intrusives.

That the ore deposits in this district are more generally associated with the dikes and apophyses of gabbro, rather than with the main stocks, is a phenomenon common to many other contact metamorphic deposits. It is believed that this is to be explained by the supposition that the dikes and apophyses are more highly charged with magmatic waters and volatile substances than the main stocks.

The depth at which the ore forming substances were released from the molten magma must have been considerable, so that the present outcrops were originally deep-seated, and have only been exposed by erosion. The typical gangue minerals, garnet, epidote, diopside, and tremolite, are characteristic of the deeper zones, and are not readily formed under conditions of medium or low pressure and temperature. Their presence, therefore, indicates considerable depth of formation. The fact, also, that this region has been subject to erosion ever since the uplift of the sedimentary rocks, which must have been in early or middle Mesozoic times, leads to the inference that hundreds, and perhaps thousands of feet of rock which once overlaid the present surface have been eroded away.

After the formation of the primary ores by the intrusion of the gabbro, there was little, though some, later enrichment from the same magmatic source. Few fractures or fissures were formed by the cooling and contraction of the igneous rocks, and of the contact zone, but those that did form became channels for the introduction of some of the enriching sulphides. Subsequent to this, ore deposition from the same source was entirely at an end. Later fractures were formed, but no new additions were received through them from a deep-seated source. On the surface, erosion and oxidation advanced deeper and deeper, and concentration of the gold values went on. Not, however, until these ore bodies came within the zone of influence of surface waters, was any change effected in them. Then the fissures, previously formed, permitted a free circulation of water, and the gold, leached out from its associated sulphides near the surface, was carried downward to enrich the ore body below. In this process concentration of values was greatest when dams had been formed by impervious cross-cutting strata.

CHAPTER III.

GENERAL CHARACTER OF THE DISTRICT.

TOPOGRAPHY.

GENERAL ACCOUNT.

Regional.—Extending northward through the State of Washington, the Cascade Mountain system gradually diminishes in height on approaching the International Boundary line. In this latitude it is made up of two distinct branches, which are merged into one large block of mountains to the south in Washington. The western branch, which contains both the Skagit and Hozameen ranges, is the stronger and more persistent one, and continues northward along the eastern side of the Fraser river, until it finally dies out in the Interior Plateau, or is cut off by the Thompson river when it bends to the east.

The eastern branch of this range continues northward, across the boundary line, as far as the Similkameen river at Keremeos, where it is abruptly interrupted by the deep valley of that stream. Northward of the Similkameen river the range is continuous in the same trend as before, but it here goes by the name of the Okanagan mountains. The crest line of these mountains is a gently sloping one to the north, and is characterized by a succession of broadly rounded summits, rising little more than 7,000 feet above sea-level. This range is neither long nor strong, and in the country about the head of Twentymile creek soon dips down to the rolling country of the Interior Plateau, where elevations barely reach 6,0[illegible] [illegible]et above sea-level. The transition from the Okanagan range to the Interior Plateau is not so abrupt as many observers would have us believe. When viewed from the west, at a point on the Similkameen river between Hedley and Princeton, the gently sloping crest line is well brought out. The highest points of the Okanagan range at the boundary line are about 8,000 feet. The upper level of the Interior Plateau, at the head of Twentymile creek, is almost 6,000 feet above sea-level. Between these two points, which are 25 miles apart the Okanagan range dips down into the Interior Plateau, and, omitting the valley of the Similkameen river, nowhere in that distance along the range is there any very abrupt change from mountain range to plateau, but there is an even slope throughout. This is the more natural way for a mountain range to die out along its longitudinal axis, and the Okanagan range being simply due to a warping of the surface along a definite line, follows the normal order and dies out by a flattening of the warped surface.

Drainage from the Okanagan range is principally toward the east and west. On the east, the streams flow either directly into Okanagan lake, or by way of Keremeos creek into the Similkameen river. On the western flank are four small but steep-graded streams flowing directly into the Similkameen river. These are Fifteenmile, Sixteenmile, Eighteenmile, and Twentymile creeks, so named by the early travellers from their respective distances above Keremeos, which was then the most important place in the valley. The largest and most important of these streams is Twentymile creek.

Between the two main forks of the Cascade range—that is to say, the Okanagan mountains on the east, and the Hozameen and Skagit mountains on the west—lies the southern end of the great Interior Plateau region of southern British Columbia. This, in the latitude of the Hedley area, or about 49° 25′, has a width of about 50 miles, quickly increasing, however, to the north. Almost exactly half way between these two ranges, in this latitude, lies the Princeton depression, toward which all slopes from the east, south, and west converge downward. In this depression the two main streams of the district unite, the Similkameen river flowing in from the south, and the Tulameen river from the west. The united streams then turn eastward and slightly southward toward the Okanagan mountains, flowing on a rather steep down-grade against what is, on the higher surface level, an up-grade, and cutting a deeper and deeper valley through these mountains until they join the Okanagan river just at the International Boundary line.

Northward of the Similkameen river and the Princeton depression, the Interior Plateau region stretches away for hundreds of miles into the northern part of British Columbia, entirely unbroken by any notable mountain ranges.

Local.—The Hedley area lies on the western flank of the Okanagan range, and only about 6 or 7 miles from its crest line. Its topography is neither that which is characteristic of a mountain region, nor is it typical of the plateau region as a whole, but it unites features which are found in both. Its higher levels are somewhat above the average of the plateau region, yet these upper levels simulate in a general way the upper levels of the plateau. The streams, however, cut so deeply into this surface, giving a vertical relief of about 5,000 feet, that, from the valley bottoms, an impression of mountain topography is conveyed.

The Similkameen river flows through the southwest corner of the Hedley area, and only two of its tributaries are here included, namely, Twentymile creek, and Eighteenmile creek. All other creeks or gulches in the area are merely tributary to the above-mentioned streams.

DETAILED ACCOUNT.

Drainage.—The general slope of the whole country in and adjacent to the Hedley district is toward the west, that is to say, toward the Princeton depression, and away from the crest line of the Okanagan range. In spite of this, the Similkameen river flows in an exactly opposite direction, or toward the east, and cuts directly through the whole Okanagan range. If one follows down the course of the stream eastward from the basin-like depression at Princeton, it is noticed that the banks of the valley rise higher and higher, and become proportionately steeper, until the axis of the range is passed through; then there is a sharp descent of the uplands, to the valley of the Okanagan river.

There is no reason to believe that the origin of the Okanagan range is different from that of the rest of the Cascade system, and it is very probable that the separate ranges which make up the Cascade system acted as a unit, and have a like history. The last uplift of the Cascade mountains in Washington is placed by Smith and Willis[1] at the close of the Pliocene, and though we have no direct evidence bearing on this point in the neighbourhood of the Hedley district, there is no reason to suppose that the

[1] U.S.G.S. Prof. paper No. 19, Contributions to the Geology of Washington.

Okanagan range was uplifted at a different period. Accepting this date as reasonably certain, we can draw some conclusions as to the history of the Similkameen valley.

It appears clear, to the writer's mind, that there must have been a valley existing on the present line of the Similkameen valley, previous to the uplift of the Okanagan range, otherwise it is difficult to account for the way in which the stream now flows eastward through this range out of the low-lying Princeton depression, and against what is, on the higher levels of the country, a strong upgrade. The general level of the Princeton depression is not more than 3,000 feet above sea-level, while the notches in the Okanagan range are generally somewhat over 6,000 feet. It is believed, therefore, that the Similkameen valley existed in its present course previous to the uplift of the Okanagan range, and that this uplift was of such a slow and gradual nature that the erosive force of the stream was strong enough to keep pace with it, and never at any time rapid enough to dam back the stream or affect its course. There is no evidence to prove that the uplift was so rapid as to materially change the course of pre-existing streams, except, perhaps, those of small volume. If such were the case, the waters of the Similkameen and Tulameen rivers could readily have found an outlet north from the Princeton basin into the Nicola River system, for the divides here are very much lower than those of the Okanagan range. It is concluded, therefore, that the formation of the Similkameen valley antedates the Pliocene uplift of the Okanagan range, and the stream is consequently an antecedent stream.

Twentymile is one of the largest tributaries of the Similkameen river between Princeton and Keremeos, a distance of 45 miles. It has a total length of only about 15 miles, and heads in a number of small branches in the plateau region along the western slope of the Okanagan range. Its volume is never very great, and on account of the aridity of the climate, it is almost dry in the late summer. Twentymile creek furnishes all the water-power for milling, haulage, and electric lighting that is used in the district, and by the conservation of its water in a small lake at the head of its east branch, sufficient is saved to tide over the dry season.

Eighteenmile, about 2 miles to the east of Twentymile creek, is smaller in volume, and shorter. Like Twentymile creek, it flows into the Similkameen river from the south. It rises on the western flank of the Okanagan range, and is only about 7 miles in length. Its water is used entirely for the irrigation of lands lying in the bottom of the Similkameen valley. These two streams, with the Similkameen river, carry all the running water of the district, all the other streams being merely intermittent.

Springs are to be found in half a dozen places in the district, but the outflow of water is very small, and these also vanish in a dry season. The fall of rain and snow is always very light, averaging about 11 inches annually at Hedley, and about 22 inches on the top of Nickel Plate mountain. Much of this water runs off immediately, owing to the high grades, but some is absorbed by the soil and rock, to slowly trickle out in springs during the remainder of the year. The quantity of underground water is not great, and never of much inconvenience in mining operations. In the early spring, owing to melting snows, there is somewhat more than in the late summer; and as the mines are nowhere timbered, some care has to be exercised at that time in the chambers and glory-holes—to avoid falling of blocks that become detached from the walls and roof by seeping water and the jar of blasts.

Grades. The grade of the Similkameen river is fairly uniform throughout the portion of its length in and adjoining the Hedley district. The difference in elevation of the bed of the stream between Hedley and Princeton is 140 feet. This for a distance of 25 miles gives an average grade of almost 19 feet to the mile. Below Hedley, if there is any variation in this grade, it is not noticeable to the eye.

A characteristic of all the tributaries of the Similkameen river in the neighbourhood of Hedley is the sudden steepening of their grades, shortly before entering the main valley. This feature was referred to in a previous report,[1] and was then attributed entirely to glacial causes. On the south side of the Similkameen valley, Henry creek, Jameson, Susanne, and Paul creeks all show this characteristic. In the case of Twentymile creek, it is not so marked as in the case of the smaller streams, which have not the same power of erosion; but even here it is noticeable. In the last 3 miles of its course the stream falls at the rate of 150 feet to the mile, and flows through a narrow V-shaped cañon, in places 1,000 feet deep.

[1] Summary Report, Geological Survey of Canada, 1907, p. 26.

Eighteenmile creek shows this characteristic much more strongly. In the last one and a half miles of its course before reaching the bottom of the Similkameen valley it falls 2,500 feet, or at the rate of 1,666 feet to the mile. For 2 miles above this—or from the 4,000 ft. contour—the stream occupies a broadly flaring valley, and has an average grade of 500 feet to the mile. This grade is then virtually constant, up to the headwaters of the stream, on the summit of the plateau. These figures indicate that Eighteenmile creek is occupying a hanging valley, the original grade of which was about 500 feet to the mile. This grade is preserved in the upper portion of its course, from a point 2,500 feet above the bed of the Similkameen river. This figure indicates the elevation at which the valley hangs. Approximately similar figures can be obtained from streams on the opposite side of the Similkameen river, near Eighteenmile creek.

The steepening of grades, and the development of hanging valleys in the tributary streams, are not of equal magnitude in streams entering the Similkameen valley at different points. The accompanying photographs, Plates III and IV, illustrate this point. In the valley above Hedley the sides are seen to slope easily and regularly downward from the level of the plateau to the bed of the stream. Below Hedley, where the valley passes into the Okanagan range, there is at first a gradual sl[illegible] downward from the highlands, as in the case above Hedley, fo[illegible] a sudden change of grade, a rounded shoulder marking [illegible]ning of a much steeper grade down to the stream bed.

In a previous report[1] it was stated that the cause of these hanging valleys was attributed entirely to glacial action. Differential erosion by the great ice sheet which covered the whole region would have its greatest effects where the ice was thickest, that is to say, over the deep valleys. Concentration of ice in the main valley, after it had left the highlands, with a consequent increase in velocity of movement, would also tend to deepen this valley, while the adjacent country escaped. It was recognized that glacial erosion had had a very marked influence in modifying the topography of the Similkameen valley, and its present form is the typical U-shape, so characteristic a result of glacial scouring. The spurs and shoulders, also, projecting into the main valley, had all been truncated and rounded

[1] Summary Report, Geological Survey, Canada, 1907, p. 26.

PLATE II

Similkameen valley, looking west towards Princeton.

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PLATE III.

Similkameen valley below Hedley

by the same action, and there are no remnants of the older river erosion remaining in the bed of the stream, all these having been removed or covered by the post-glacial deposition of sediments.

The hanging valleys may, however, have been brought about by totally different causes. The uplift of the Okanagan range, and the adjacent plateau region, may have been so gradual that the erosive force of the Similkameen river was able to keep pace with it by cutting down its bed at the same rate as the uplift. In the case of tributary streams, however, the volume of water of which was small, and erosive force correspondingly weak, the same rate of uplift would be too rapid to allow them to acquire a uniform grade throughout, and sufficient time has not yet elapsed to bring about this result. Consequently, these streams have a sharp break in their grade.

If this theory is correct, it follows that the difference in elevation between the bottom of the Similkameen valley and the point where the change in grade occurs on each stream, represents the minimum amount of uplift that has taken place at each of these points in the late Pliocene times. This difference on Eighteenmile creek, which is about 4 miles from the crest of the Okanagan range, is about 2,500 feet. Evidence in support of this theory of warping, as the cause of the hanging valleys, is furnished by the accompanying illustrations, Plates II and III. These show that hanging valleys are not so high or well marked in the region above Hedley to the west, as they are in the part of the valley below Hedley. The former is in the plateau region where the uplift was relatively lower, while the latter is in the Okanagan range where the uplift was at its maximum.

After carefully considering the evidence, the present shape of the Similkameen valley and the tributary hanging valleys is believed to be due partly to differential warping, and partly to unequal glacial erosion, each of which has had its effect on the physiographic history of the region. In the development of this topography, the first cause was the rapid cutting down by the Similkameen river of its own bed, concurrently with the uplift of the Okanagan range, and the formation of a narrow V-shaped cañon, as a result. The tributary streams, with their small volume, could not erode their beds fast enough to produce a uniform grade throughout, and a broken grade resulted, with a steepening of the lower portion to approximately the present gradient. On the occupation of this region by glacial ice, the V shaped valley of the Similkameen river was used as an outlet for the accumulated ice in the northern plateau region, and modification of its shape at once began. The valley may have been deepened somewhat, and it was probably also widened at the bottom, and projecting shoulders were rounded off. This action would also tend to accentuate the hanging valley effect of the tributary streams. Finally, on the melting and recession of the glacial ice, streams overladen with debris carried down and deposited the gravels which help to give the valley its present shape. To thoroughly appreciate the action of glacial ice on the topography of the Similkameen valley, one should attempt to recall the conditions as they existed at different stages of the glacial period. If we follow Dr. R. A. Daly, who has estimated the maximum elevation of ice in the Boundary section at the height of the glacial period, as 7,500 feet above sea-level, we would get a thickness of about 6,000 feet of ice in the Similkameen valley, while the neighbouring uplands would only have from 1,000 to 1,500 feet. Differential erosion would naturally result, with the greatest amount in the parts over which there was the greatest load. If, however, we consider the conditions existing both before and after the glacial period was at its height, when the ice only filled the main valley without covering the adjoining uplands, we can understand the tendency to concentrated erosive action in the deeper valley, while the uplands suffered comparatively little in this respect.

The figures given above for the grade of the Similkameen river indicate swiftly moving water, and strong erosive force. The transporting power of the stream under this grade is such that only boulders, gravel, and coarse sands remain in the bed. The finer sands and suspended material are all carried far below this district before they come to rest. Very much heavier grades obtain in the tributaries of the Similkameen river, so that they flow for much of their courses over bed-rock. In the smaller gulches, tributary to Twentymile creek, the grades are so high that only a small amount of water is necessary to transport the rock waste down to the larger stream, and in many cases the degree of slope is just about equal to the angle of rest of the rock waste.

Relief.—In general aspect, the higher levels of the Hedley district are almost flat, or gently rounded in outline. The district lies in a more elevated portion of the Interior Plateau region, the general

PLATE IV

Talus slope on Twentymile creek

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features of which have been well described by Dawson, Daly, and other geologists. In a broad survey of this plateau region from any one of the higher points, one would hardly suspect the presence of such deep valleys as those of the Similkameen river, and Twentymile creek. In the general uniformity of level of the plateau, these deep trenches give no evidence of their presence, and consequently come as a great surprise. The elevation of the highest point of the Hedley district is 6,660 feet above sea-level, that of the lowest point is 1,560 feet, so that there is a total vertical relief of 5,100 feet. The rounded outline of the higher levels represents an older cycle of erosion, antedating the late Pliocene uplift and probably to be referred to the Eocene peneplanation; while the lower levels are the result of a second cycle, when increased power of erosion had been given to the stream by uplift of the Interior Plateau region, and a warping of the Okanagan range. The narrow V-shaped cañon of Twentymile creek is the result of this second cycle, aided and exaggerated, it is true, by selection by the stream of certain lines of weakness in the rocks. The portion of the valley lying within the limits of the map is very strongly V-shaped, and from 2,000 to 4,000 feet in depth. Its slopes on either side are very steep (about 35°), and characterized by broken rock talus and precipitous bluffs. The tributary gulches entering the cañon are often nothing more than deep gashes in the mountain side, and though deep, are, on account of their narrowness, almost imperceptible from the opposite side of the valley.

The action of erosion in Twentymile cañon is very strong, and is equal if not in advance of the decomposition of the rocks by oxidation. Every shower of rain throughout the summer washes down the cañon sides quantities of rock waste, and dislodged masses of rock, to such an extent that it is unsafe to be in the cañon at such times.

In a general way, the steepness of the slope is dependent on the solubility of the rocks and their debris. The igneous rocks of the district are generally quite as resistant to atmospheric weathering as the sedimentary, or even more so. The granodiorite and gabbro-diorite rocks form the larger proportion of the cliffs; while sedimentary rocks, particularly where they are calcareous, generally show easier grades. In many portions of the eastern side of Twentymile creek the degree of slope is determined entirely by the dip of the rocks, the one coinciding with the other.

The upper levels of the district have a totally different kind of topography to that found in the cañons, and represent an older cycle of erosion previous to the Pliocene uplift. Here we have forms which are characteristic of the plateau region as a whole. The summits are almost flat, or broadly rounded, and the sides of the valleys flare out widely. The slopes are so gradual that drift will easily rest on them, and outcrops only occur in the case of the more resistant rocks. The more soluble limestone bands can generally be identified, even under the covering of drift, by slight depressions or more graded slopes, while the harder rocks are marked by slight ridges. The mature relief of these higher levels has been to some extent brought about by glacial action, more particularly that of deposition. The tops of the hills have no doubt been somewhat rounded by glacial erosion, but deposition of debris in the depressions has contributed far more to a reduction of the relief.

CLIMATE AND AGRICULTURE

The climate of that portion of the Similkameen district in which Hedley is situated is a very pleasant one. As the region, however, is one of rather strong relief, the variations of temperature and precipitation between the bottoms of the valleys and the higher portions are very marked, even at points not far separated from each other. As an illustration of this, a comparison between observations taken at Hedley and those taken at the Nickel Plate mine is interesting. These two points, though only 3 miles apart, have a difference in elevation of 4,000 feet. The accompanying table gives the average precipitation in inches for each month at these two points for the last four years, up to August, 1908:—

	Hedley. Inches.	Nickel Plate. Inches.
January	0·48	1·40
February	0·64	1·71
March	0·67	1·97
April	0·39	1·69
May	1·95	3·56
June	1·09	2·53
July	1·19	1·82
August	0·89	1·16
September	1·00	1·27
October	0·53	1·32
November	1·16	1·83
December	0·80	1·53
	10·79	21·82

This table shows the average annual precipitation at Hedley to be 10·79 inches, while that at Nickel Plate is 21·82 inches, or about twice as much. It also shows that the greatest precipitation comes in the months of May and June, while no particular month can be said to be markedly drier than any other. Very little snow ever falls in the bottom of the Similkameen valley from Hedley downward, so that the total precipitation there must be charged to rain. At the Nickel Plate, however, snow is known to fall every month of the year. The climate of Hedley is a distinctly dry one, and the camp must be considered to form part of the dry belt of British Columbia, which lies along the eastern flank of the Coast range of mountains. The cause of this dry character is found in the fact that the high and wide Coast range intercepts all the moisture carried eastward from the Pacific ocean by the prevailing easterly winds.

This dryness is a factor which has to be reckoned with by companies who contemplate the erection of stamp mills in the district for the treatment of the Hedley ores. The supply of water in Twentymile creek is not even sufficient to provide power for the Daly Reduction Company's mill, and they are compelled to conserve the season's rainfall in a lake at the head of the creek, for use during the dry season. The Similkameen river, however, carries a considerable volume of water the whole year round, and this would undoubtedly be available for the development of power, if mining operations demanded it. The grade of the stream is steep, and the volume of water that comes down in June and July, during the melting of snows in the mountains, is very much greater than that flowing during the rest of the year, so that means would have to be devised to meet both conditions.

Temperatures at Hedley have a wide range, though the mean for the whole year is about 45° F. The summer mean is about 60° F. The months of July and August are very hot, and the temperature occasionally goes up to 100° in the shade. The winters are never very cold, though it sometimes reaches 15° below zero. The average barometric pressure for the year for the elevation of 1,600 feet above sea-level is about 29·95.

Taken as a whole, the country is well wooded, though not thickly. The southern slopes of the hills are frequently quite open and grassy (See Plate V), and when wooded, have an open park-like appearance.

The northern slopes are always timbered, and the eastern and western generally so. The common trees are the yellow pine, fir, black pine, aspen, spruce, and balsam, with some cedar and birch. On account of the dryness of the climate, much of the timber has been destroyed by forest fires; much, however, is yet available for use in mining operations.

There are great areas of excellent pasturage for horses and cattle, and bunch grass (*Agropyron spicatum*) and pine grass (*Koeleria cristata*) are the common grasses, with wild peas and vetches in certain places.

In the immediate vicinity of Hedley, land available for agriculture is confined to the bottom of the Similkameen River valley. This is also true of the region lying 20 miles east and west of Hedley. The valley bottom is from one-half to three-quarters of a mile wide, and at Hedley has an elevation above sea-level of about 1,600 feet. On either side there is a steep and unbroken rise for at least 3,000 feet higher before the lower levels of the plateau region are reached, and at this level, cultivation of the ground can be successfully carried on only to a very limited extent, on account of the prevalence of frosts throughout the summer. All agricultural pursuits, therefore, are confined to the main valley, for the tributary valleys are nothing more than V-shaped notches in which very little soil is found.

Farms are scattered all the way through the valley from one end to the other, and are quite sufficient to supply the present needs of the district in vegetables and garden produce. There is room for many more yet; but much of the land is held in trust by the government for the Indians, and if they do not cultivate it, no one else is allowed to.

Various kinds of fruit are successfully grown as high up the valley as Princeton, 25 miles above Hedley. At Hedley itself, apples, plums, and peaches all do well, though only a small number of trees are yet bearing. Pears and grapes are grown a few miles below Hedley, and at Keremeos. Although the area of land available for agriculture is small, its quality is good, and as the population increases, more and more will undoubtedly devote their energies to fruit raising, until this becomes an important industry in the district.

PLATE V.

Open southern slope of Lookout mountain.

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CHAPTER IV.

GENERAL GEOLOGY.

GENERAL STATEMENT.

Regional.

The geology of the whole region, of which Hedley forms a part, is very little known as yet. The only geological map of the region, namely, that of Dawson in 1877, is correct only as far as the routes traversed by him are concerned. The region on either side of these routes was then and is still almost unexplored, and little is known of its geology. It is not to be expected, therefore, that the geological formations as defined on that map will be found in all instances to be correct. In a general way, the geology of the region may be outlined as follows: lying some distance to the east of the Hedley quadrangle, and exposed on the eastern side of Okanagan lake, is a series of old crystalline rocks, called the Shuswap series, and representing the old Pre-Cambrian axis of British Columbia. Overlying these rocks on the west is a thick series of sedimentary rocks, presumably of Carboniferous age, called the Cache Creek group, and represented by limestones, cherty quartzites, siliceous argillites and volcanic materials. These sedimentary rocks have everywhere been intruded by igneous rocks to such an extent that little of them now remains, and this very often only as isolated patches in the batholithic rocks, completely separated from each other. These igneous rocks appear to cover a much larger area than any of the earlier or later sedimentary rocks, and they represent periods of eruptive activity, extending through a great part of Mesozoic times, and into Tertiary. It is in an area of Cache Creek rocks that the greater part of the Hedley district lies. How large this particular area may be is not yet known, but it is certain that it is completely cut off on the north, west, and south by granitic rocks, and its greatest areal extent is toward the east. In this direction it extends for perhaps 10 or 12 miles, or more, until covered by volcanic rocks of Tertiary age.

Overlying the Cache Creek rocks, as well as the granitic rocks, are small areas of Oligocene sediments containing lignite beds, occurring in isolated depressions in the older rocks. The best known of these lignite basins is the Princeton basin, about 20 miles west of Hedley. Other similar areas are known to occur, which have not yet been studied or mapped. Volcanic effusive rocks of post-Oligocene age overlie the lignite beds, and have a very wide distribution throughout the whole region.

These are the only rocks known to exist within a radius of 25 miles of the Hedley quadrangle.

Local.

The oldest rocks of the Hedley area are sedimentary rocks, presumably of Carboniferous age, and correlated with the Cache Creek group of Dawson's Kamloops map sheet. These are the only consolidated sediments in the area, and they include, besides the true sedimentary rocks, a great thickness of contemporaneous volcanic materials, generally of explosive volcanic origin. They have been tilted in a general direction toward the west, and they now dip at angles varying from 15° to 90°.

Eruptive rocks have been intruded through these rocks in the following order: (1) quartz diorite and gabbro; (2) granodiorite. These igneous rocks have been accompanied or followed by many dikes of different compositions, porphyries, lamprophyres, andesites, and rhyolites.

The last and most recent group of rocks in the sequence are the unconsolidated deposits of sand, gravel and silt, of glacial and post-glacial origin, which are generally found lying as a thin mantle over the older rocks, or forming the floors of the valleys.

TABLE OF FORMATIONS.

In the accompanying table the different geological formations are arranged in descending order, according to age, and it includes the igneous as well as the sedimentary bodies.

Quaternary.—Stream deposits and glacial drift.

Tertiary.—Granodiorite.

Mesozoic.—Diorite and gabbro.

Carboniferous.—Cache Creek group.

(4.) Aberdeen formation.

(3.) Red Mountain formation.

(2.) Nickel Plate formation.

(1.) Redtop formation.

SUMMARY DESCRIPTION OF FORMATIONS.

Cache Creek Group.

The sedimentary rocks of the Hedley quadrangle have been correlated by Dr. Dawson with the lower Cache Creek group of the Kamloops map sheet, in which Carboniferous fossils are found. In the entire absence of any determinable fossils here, this correlation has been based entirely on lithological features. It is certain, however, that there is a very marked resemblance between these rocks and those of the original Cache Creek group, and it is altogether likely that if any palæontological evidence is ever obtained, this correlation will be confirmed. Neither a top nor a bottom has been discovered to the series in the neighbourhood of Hedley, for granitic intrusions have cut off the beds at both ends. The various formations which together make up the whole group are conformable with each other. There is, however, an approach in certain portions to littoral conditions, even to the development in them of a small area of fine-grained limestone conglomerate, but even here there is no evidence of an unconformity.

For the purpose of mapping and description, the group has been divided into four separate formations. Although these formations are generally, though not in every case, well-individualized units, the precise horizons of division planes that separate them from each other are matters of arbitrary selection. Without exception, contiguous formations grade one into another, and they all succeed each other conformably. The lines separating the different formations will be described as clearly as possible, later on. A brief characterization of the different formations will first be given, in order to indicate the grounds for an attempted correlation with the typical Cache Creek rocks of the Kamloops map sheet.

Redtop Formation.—The name Redtop, like all the others here given to the divisions of the Cache Creek group, is a local one, applied to the lowest beds of sedimentary rocks occurring within the limits of the sheet. These are best exposed on the north slope of the Similkameen river in Redtop gulch. They consist largely of siliceous rocks, occurring generally in thin beds, intercalated with bands of limestone at the top and bottom, and with argillaceous and volcanic bands toward the middle of the series. They are seen in the eastern part of the area to have as a base a massive limestone, called for the sake of convenience in describing it, the Stevenson limestone. This limestone is cut off by the eruptive granodiorite, and only a relatively small exposure of it appears.

The Redtop formation is strikingly banded, due to the rapid alternation of light and dark bands of rock. The light bands are generally white or greyish quartzite, while the dark bands are either black argillaceous quartzites or limestone, or beds of black volcanic material. The Redtop formation is characterized in general by shallow water conditions and rapid changes in sedimentation, with many outbursts of volcanic activity.

Nickel Plate Formation.—The Nickel Plate formation is so named from the Nickel Plate mine, which occurs in it. In this formation are found all the most important ore bodies yet discovered. In contrast to the preceding formation, which is essentially quartzite, the Nickel Plate formation is eminently calcareous. The base of the formation is represented by the Sunnyside limestone—a greyish blue or dark blue massive limestone, about 300 feet thick, forming a continuous band, which can be traced without interruption through a large portion of the area. At the top and bottom of the Sunnyside limestone bed there is a gradual transition, by an increase in the quantity of intercalated quartzite bands into the Redtop formation below, and into the middle beds of the Nickel Plate formation above.

The middle of the Nickel Plate formation consists essentially of interbedded limestones, and some quartzites. They are all so much metamorphosed by contact igneous action that it is difficult to obtain a correct idea of their original lithologic character. Many of the beds, now highly siliceous, were undoubtedly originally limestones. Quartzites increase toward the top of the formation, but the topmost bed of all is again a massive limestone coarsely crystalline, and light grey in colour, and called the Kingston limestone. The volcanic materials of the Red Mountain formation overlie the Kingston limestone; but in places local accumulations of these volcanic beds have been intercalated between the Kingston limestone and the remainder of the Nickel Plate formation, cutting off the limestone altogether. When it is separated from the rest of the formation the Kingston limestone is brecciated.

The top and the bottom members of the Nickel Plate formation represent two of the longest periods of quiet, stable conditions that we have in the whole of the Cache Creek group of Hedley.

Red Mountain Formation.—This formation is made up entirely of volcanic materials, is not continuous throughout, nor does it everywhere overlie the preceding formation. It is found, rather, as local developments and wide lenses, between the Nickel Plate and Aberdeen formations. The rocks consist essentially of fragmental volcanic materials, making up a succession of beds which appear to have been deposited in water. The materials of which the beds are made up are of very variable fineness, from microscopic particles to large, coarse blocks. In contrast to the banded appearance of the other formations, these rocks are characteristically massive. They contain a great deal of iron sulphides, and, in consequence, weather easily to a dark reddish colour.

This formation attains its maximum development on Red mountain, where on account of its great resistance to erosion, it forms steep conspicuous bluffs and precipices.

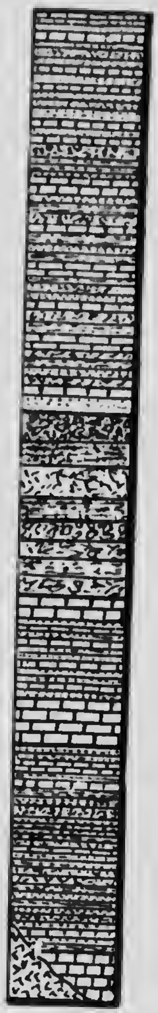
Aberdeen Formation.—The Aberdeen formation is so named because the beds are best seen in the neighbourhood of the Aberdeen ridge and below it to the bed of Twentymile creek. This is made up of a very thick accumulation of true sediments, and some volcanic materials, the former consisting of bands of dark blue and white limestone, light coloured quartzite, and dark siliceous argillites. These separate beds are usually thin, and the frequent change from dark to light gives the exposures a beautifully striped and banded appearance. The light coloured bands are usually quartzites or white limestones, while the dark bands are either dark blue limestones, siliceous argillites, or fine-grained black volcanic tuffs. The metamorphism of some of the limestone bands to garnet or epidote often introduces shades of green, brown, or dark red in the exposures. The thickness of these bands is generally very little more or less than 1 foot, and the banded character of the whole series is well brought out in the steep cliffs of Stemwinder hill, overlooking the town of Hedley, and particularly when the rocks have been washed clean by recent rains. The attitude of the Aberdeen formation is generally steep, and the rocks all dip at very high angles to the west, or are vertical.

The succession in descending order, general lithological character, and approximate thickness of the different formations, are summarized in the following generalized table:—

Generalized Tabular Section of the Cache Creek Group at Hedley.

	Feet.
(4). *Aberdeen Formation.*—Consisting of interbanded cherty quartzites, limestones, siliceous argillite, and volcanic materials, all in thin beds, indicating rapid changes in sedimentation, and frequent outbursts of volcanic activity	3000+
(3). *Red Mountain Formation.*—Consisting essentially of beds of volcanic materials, fine tuffs to coarse breccias, regularly bedded, and indicating deposition in water. Essentially local and quickly pinching out between true sediments. Maximum.	1200
(2). *Nickel Plate Formation.*—Consisting of massive limestones at the top and bottom, with interbanded quartzites and siliceous limestone in the middle.	900
(1). *Redtop Formation.*—Consisting of interbanded limestones, cherty quartzites, siliceous argillites, tuffs, and some breccia, resting on a massive limestone, the base of which is cut off by granitic intrusion.	1200+

Generalized Columnar Section of the Rocks of the Hedley Sheet.



Aberdeen Formation.—Interbanded limestones, quartzites, argillites, and volcanic materials.

Red Mountain Formation.—Volcanic materials, tuffs, breccias.

Kingston Limestone.

Nickel Plate Formation:—Massive limestone and interbanded limestone, and quartzites, thin-bedded.

Sunnyside Limestone.

Redtop Formation:—Quartzites, argillites, volcanic materials, and some limestone.

Stevenson Limestone.

IGNEOUS ROCKS.

With the exception of the pyroclastic rocks associated with the Palæozoic sediments, all the igneous rocks of the district are intrusive in origin. According to form or method of intrusion, they might be classed as batholith, stocks, apophyses, and dikes and sheets. All are found in intrusive relation to the Cache Creek sediments, and all were intruded after deposition had ceased. The order of intrusion of the larger bodies has been marked out in detail, but the relation of some of these bodies to the dikes is yet in doubt, as they have not been found in contact with each other.

The oldest of these igneous rocks is considered to be of Mesozoic age; the reasons for placing them here will be discussed later. This is the diorite-gabbro complex, and its rocks occur in thin, distinct, stock-like masses, and in several intrusive bodies of irregular form, besides in large numbers as apophyses from those. The most common rock of this composite formation is a diorite, which, with the addition of quartz, becomes a quartz diorite. Its constituents are plagioclase feldspar, and green hornblende, with a smaller proportion of orthoclase and quartz. With this is associated a gabbro which is intrusive into the diorite, but only very slightly younger in time of intrusion. The gabbro is of uniform texture and composition, and is white, or very pale greenish in colour. It is composed of plagioclase feldspar, and very pale greenish pyroxene, which proves to be diallage. There is a close consanguinity between the diorite and the gabbro, and it is difficult to separate them on account of transitions between them. This transition is more apparent in the apophyses from the main bodies. In the massive forms, while a transition is sometimes seen, it is more common to find a contact. This contact is of such an indefinite nature that the conclusion was drawn that the gabbro was intruded into the diorite before the latter had quite solidified, and while it was still in a plastic condition. The whole formation is considered to have been at one time one homogeneous magma, which by differentiation separated into different parts, of which the quartz diorite is one extreme, and gabbro the other. These rocks cover a large area in the district, and are of great economic importance as being concerned in the formation of the ore bodies.

An igneous rock of later date than the diorite-gabbro formation is a granodiorite, which has been referred to Tertiary age. Though in many places concealed by drift and gravel deposits, this probably covers a much larger area than any of the other igneous bodies. It appears in this district as part of a great batholith, which has a wide areal distribution to the south and west. It is a rather basic granodiorite, and is more nearly related to diorite than to granite. It is a uniform rock of coarse granitic texture, and even grain, and is made up of orthoclase and plagioclase feldspar, the latter in excess, and quartz, hornblende, and biotite.

The dike rocks of the district are of various kinds, and of different ages, some being cut by the granodiorite batholith, and others intrusive into it. Lamprophyre dikes belong to a period earlier than the granodiorite, but later than the diorite-gabbro. Aplites and quartz porphyries appear to be connected with the granodiorite intrusion, while some soft green andesites are later than this event. No uniformity of trend in all the dikes can be made out, but in the younger ones there is a tendency to parallelism in a north and south direction of strike.

QUATERNARY.

The Quaternary deposits of the Hedley area consist entirely of unconsolidated materials of glacial and post glacial origin. The former are found as a thin mantle overlying the older rocks and are seen everywhere on the higher levels. The deposits of post-glacial origin are found as stream deposits in the bottom of the valleys. These form a very thick deposit, into which the present streams are incising their channels, forming well marked benches to denote the different levels at which the water formerly stood. They are not of much economic importance, and consequently have not been very closely studied.

DETAILED DESCRIPTION OF FORMATIONS.

REDTOP FORMATION.

Distribution.—The Redtop formation includes all the sedimentary rocks inside the sheet lying below the base of the Sunnyside limestone. The contact with the Sunnyside limestone is a fairly well-defined line, which can generally be identified when exposed. The lower boundary of the formation, however, is arbitrarily fixed at the contact of the eruptive granodiorite, and it is impossible to say how great a thickness of these beds originally lay below the lowest bed now seen.

The Redtop beds are most extensively developed in the south-eastern portion of the sheet. They directly underlie the Sunnyside limestone, but in the western part of the sheet the base of the Sunnyside limestone is not exposed, so that the Redtop beds are not seen. Along the eastern border, also, where this occurrence would be expected, they are largely covered by drift; but here, one or two small outcrops of igneous rock indicate that they may be cut off in places almost up to the base of the Sunnyside limestones.

The best exposures are seen in the Redtop gulch and on the face of Striped mountain, overlooking the Similkameen river, where their banded appearance, accentuated somewhat by sheets of igneous material, suggested to Dr. Dawson the name Striped mountain.

The Redtop beds have not yet yielded anything of economic importance in the way of ores, but there is no reason to believe that under favourable conditions of igneous intrusion the formation should always be barren.

Thickness.—The best estimate of the thickness of the Redtop formation is obtained from an east and west section across from Striped mountain to Eighteenmile creek. The thickness obtained here, however, can only be an approximation, as for a great part of the distance the beds are covered by drift, and it has to be assumed that the dip in this part is constant throughout. This assumption might probably be borne out by the facts; but there is also some close folding to be seen in Redtop gulch, which may indicate a repetition of beds in the part that is covered by drift. The minimum value obtained for these beds is 1,200 feet.

Lithology.—Owing to the lack of any continuous exposure, the succession of strata cannot be worked out in detail. The lowest bed of this formation is a massive limestone, which is truncated by the granodiorite intrusion. This limestone is light grey in colour, granular, and in places crumbles easily. It is best seen on the west side of Eighteenmile creek, overlooking the Similkameen river.

Above the limestone the strata are covered for some distance, but when again exposed, they are seen to have changed from calcareous to highly siliceous rocks. The bulk of this middle portion of the formation consists of very fine-grained cherty quartzites, with which are interbedded layers of volcanic material, and [illegible] siliceous argillites. The cherty quartzites vary in colour from white to dark grey, and some are light green. The beds, as a rule, are not heavy, generally only a few inches or even a fraction of an inch thick, and show rapid changes in sedimentation. On account of the readiness with which they break up, they give rise to talus slopes made up of very small fragments.

The volcanic beds intercalated with these cherty quartzites are themselves very siliceous, of variable thickness, and, as a rule, not continuous over large areas. In the Redtop gulch, some thin reddish bands, often less than 1 inch in thickness, are thought to be of volcanic origin, and it is considered that they are simply local accumulations of ash-material, laid down under water contemporaneously with the enclosing quartzites. Afterwards, these ash-beds were compacted, and later still, altered by metamorphic action, connected with igneous intrusions, which also affected the adjoining beds.

If continuous, these middle quartzitic beds should again be found on the western edge of the map below Sunnyside No. 1 glory-hole, and near the forks of Eighteenmile creek. Nearly all of this part, however, is covered with drift, and the few exposures of rock which appear, only tend to make the study of them confusing.

Outcrops of a very hard siliceous breccia, too small to give any idea of its stratigraphic relations, have been exposed by miners in their prospecting operations in this portion of the district. This breccia may be a bedded volcanic deposit, having its counterpart in the thin bands of volcanic material in Redtop gulch. Between the forks of Eighteenmile creek, however, where it is again exposed, though outside of the sheet, the attitude of the breccia is almost vertical, and it here suggests a formation by intrusive contact with igneous rocks. In other portions of the district, particularly at Central station, on the gravity tram-line, and north of the Nickel Plate mine, breccias of undoubtedly explosive volcanic origin, but which are interbedded with true sedimentary rocks as if laid down in water, are well exposed; so that it is probable the breccia above referred to is of similar origin.

Above the essentially quartzite beds of the middle portion of the Redtop formation, there is a gr[illegible] ney to a change in sedimentation to clearwater cond[illegible] [illegible]stone. The transition was not sim[illegible] limestone, but rather a series of rapid changes in sedimentation, during which there was an alternation of siliceous and calcareous beds, with each time a stronger tendency toward the formation of calcareous beds, until a point was reached when the changes ceased, and conditions remained stable for a long period of time, to allow the deposition of the Sunnyside limestone. As a result of these changes in sedimentation, we have bands of limestone from 6 inches to 1 foot thick, interbedded with the other rocks.

This period was not without its intervals of vulcanism, and we find beds of fine-grained black tuffs, and some breccia intercalated with the limestone and quartzite, denoting outbursts of volcanic activity. Interbedded with all of these are other black layers, which are now very siliceous, but which may originally have been largely argillaceous in composition.

The uppermost bed of the Redtop formation on Striped mountain is seen to be a breccia, in places about 2 feet thick, which contains fragments apparently of the lower bed, much metamorphosed and cemented together with a calcareous cement. Even in some of the small limestone bands, one occasionally sees small fragments of foreign material, apparently volcanic ejectamenta, embedded in the limestone, indicating that even in the quiescent periods of limestone formation there was volcanic activity going on at no great distance.

The alternation of beds, and the consequent banded appearance of the upper Redtop beds, are well shown on Plate VI.

A peculiarity of some of the upper limestone beds of the Redtop formation, as well as of some of those of the Nickel Plate formation above it, is their emission of a fœtid odour of sulphuretted hydrogen, when struck with the hammer.

The attitude of the whole formation in general shows a fairly uniform dip of about 35° to the W N W. When examined in detail, however, one notices a few examples of complete folds of small magnitude, particularly in subsidiary cañons on the west side of Redtop gulch. Here also are some minor faults, with throws of a few feet, which strike almost north and south. The whole formation has suffered considerable metamorphism as a result of orogenic movements, but a great deal more contact igneous action.

Microscopic Characters.—When studied microscopically, the rocks of the Redtop formation furnish little information that is not already obtained from a field study of them. This is especially true of the

Banding in the Redtop formation.

calcareous members of the formation. In the case of the siliceous and volcanic members, it is practically impossible to get away from the effects of metamorphism by contact igneous action, so that the microscope simply reveals what the characters of the beds now are, without giving much hint of what they originally were, before metamorphism. Sections of the light-coloured cherty quartzites show a rock of exceedingly fine grain, made up of quartz, epidote, and iron sulphides. The epidote occurs either in small isolated individual grains, or in irregular areas made up of an aggregation of small grains. Some garnet is occasionally associated with the epidote. The bulk of the sections, however, appears to be made up of silica, either as small angular grains of quartz, or as an almost isotropic mass of chalcedonic silica, forming the ground-mass in which the epidote and quartz are embedded. The chalcedonic silica is probably of secondary origin, and may have replaced some of the original constituents of the rock. It is difficult to say what the original composition of these rocks may have been, but it is certain that they were to some extent calcareous, and also somewhat siliceous. They were undoubtedly rocks that lent themselves very readily to alteration by contact metamorphism, for metamorphism has extended farther into these rocks than into the limestones that are interstratified with them. This may have been due to greater porosity, and it is quite possible that the original rock was a loose fine-grained volcanic tuff, that was later silicified and compacted.

A characteristic feature of these cherty quartzites is the occurrence in them of very small fissures, which are, as a rule, filled with quartz, but which often contain some calcite in addition. Occasionally these fissures are filled with well crystallized laths of feldspar.

Fine-grained reddish rocks, with a harsh feel, interstratified with the cherty quartzites, are taken to be metamorphosed tuffs. The thin section shows them to be very fine-grained, and made up of small angular grains of quartz and feldspar, and lath shaped crystals of brown mica. Some of the grains are almost isotropic, and might be glass, more or less devitrified. Iron ores—both pyrite and magnetite—are very abundant.

The argillaceous rocks interstratified with the above are seen under the microscope to be very siliceous, and contain crystals of feldspar. An opaque and probably carbonaceous substance is abundant, showing a tendency to flow structure, by curving around the quartz and feldspar grains.

The massive limestone at the base of this formation is only slightly metamorphosed, even though it is cut by the large mass of granodiorite forming the base of the hill. The siliceous and tufaceous beds, on the other hand, which make up the bulk of the centre of the formation, are highly metamorphosed, the metamorphism extending over practically the whole of these beds seen.

NICKEL PLATE FORMATION.

Distribution.—The Nickel Plate formation is much better defined than the underlying Redtop formation. Its top and bottom members are two fairly distinct and individualized beds of massive limestone, the lower being known as the Sunnyside limestone, and the upper as the Kingston limestone. The complete section from the base of the Sunnyside limestone to the top of the Kingston limestone is only seen in a steep bluff overlooking the town of Hedley, on the eastern slope of Twentymile creek. Over a great part of the area to the east of this the upper limestone bed has either been eroded away, or has been so changed by contact metamorphism as to be unrecognizable. In the northern part of the sheet, the Kingston limestone is completely separated from the remainder of the Nickel Plate formation by local accumulations of volcanic material, and appears, after an interval on Red mountain of several hundred feet, as a brecciated bed. Overlying the Kingston limestone at this place are more volcanic materials. In the northwestern part of the sheet the Nickel Plate formation passes conformably into the Aberdeen formation above, without the intervention of the volcanic materials of Red mountain, which here pinch out.

The Nickel Plate formation, while not being as thick as either the Redtop or Aberdeen, attains a much greater areal development than either of these. It forms a broad band entering the sheet at the northeast corner, and passing diagonally across it to the southwest, where it is cut off by the granodiorite at the junction of the Similkameen and Twentymile valleys.

Economically this has proved to be the most important formation in the whole camp, for in it are the important ore bodies of the Nickel Plate and Sunnyside mines, and other promising prospects on the eastern slope of Twentymile creek. Other discoveries of importance are to be looked for in the rocks of this formation.

Thickness.—The work of making an estimate of the thickness of this formation is complicated by the great number of intrusive sheets of igneous rock which are found in it. Local accumulations of volcanic materials are also wedged into the upper members, and unless all these are eliminated from the total obtained, the result is a figure to which the formation is by no means entitled. A section east and west through the steep bluff overlooking the town on the east side of Twentymile creek gives a result that is, perhaps, more nearly correct than can be obtained elsewhere in the camp, for here volcanic beds are entirely wanting, and intrusive sheets are so few and well exposed that their thickness can be estimated with reasonable accuracy. This section gives a total thickness for the Nickel formation of about 900 feet, of which about 300 feet must be credited to the massive Sunnyside limestone member.

Lithology.—The Nickel Plate formation shows lithologically much greater homogeneity than either of the other two strictly sedimentary formations. Volcanic materials as intercalations are noticeably wanting, and the whole formation is essentially calcareous.

On account of erosion of the upper members—or truncation of these by igneous intrusions—it is almost impossible to get a complete section. On the eastern slope of the Nickel Plate mountain, where one might expect to get the best section, both on account of the dip, and on account of the smaller number of igneous intrusions, the beds are generally covered by drift, and exposures are rare. On the western slope of the mountain, going down to Twentymile creek, the dip of the rocks almost coincides with the slope of the surface, so that only the uppermost beds can be seen. A sharp break in the regularity of this slope, however, occurs about 1,300 feet above the bed of Twentymile creek, and a steep precipitous bluff is formed which gives an excellent exposure of a great part of the Nickel Plate formation. (See Plate VII).

A three-fold separation of the whole Nickel Plate formation might easily be made on lithological grounds. These divisions would consist, first, and in the lower part, of the massive limestone called the Sunnyside limestone; second, a middle division of alternating bands of limestone and quartzite, with the limestone greatly preponderating, and at the top a third division, consisting again of a massive limestone known as the Kingston limestone. These divisions are not separated from one another by any well-defined lines, but there is rather a gradual transition by increase or decrease of quartzite bands from one to the other, so that different observers might not select the same division plane.

The lowest member of the formation is the Sunnyside limestone, which has a thickness of about 300 feet. The physical appearance of the limestone varies from a light grey coarsely crystalline rock, which crumbles readily, to a more compact dark blue variety, the latter predominating in the upper portion of the bed. Some very thin, irregular, and not continuous layers of cherty rock are occasionally interbedded with it, and these are rarely more than an inch or two in thickness. Toward the top, the Sunnyside limestone is white and coarsely crystalline in bands. This limestone is one of the most distinctive bands in the whole camp, and was very useful in tracing out the horizons adjoining it. It forms bold cliffs on the face of Striped mountain: but on the eastern slope of the mountain its outline is only marked by a gentle even slope, contrasting with the bolder topography of the more resistant rocks.

The Sunnyside limestone represents one of the few periods—and probably the longest—of quiescence in the whole history of the Cache Creek group of Hedley; and whether the cherty layers represent a change in sedimentation or volcanic disturbance, or merely metasomatic replacement, the length of time required for the formation of these bands is relatively short.

The middle division of the Nickel Plate formation has an approximate thickness of 500 feet up to the base of the Kingston limestone. This portion of the formation lends itself much more readily to contact metamorphism than either of the adjoining divisions, and its mineral composition has been so changed thereby, that it is impossible to obtain a correct idea of its original character. It forms the upper portion of the Nickel Plate mountain above the Sunnyside limestone, and holds the large ore bodies here being worked. It is, however, greatly intruded by dikes and sheets of igneous rock, which have doubtless induced some change in composition, as well as to some extent destroyed the original structure. Following these beds toward the south and west, past the Yale Mining Co.'s tipple and Central station, and down to the steep bluff on Twentymile creek overlooking the town, frequent outcrops are obtained, many of which are only slightly altered by contact metamorphism, and from these some idea of their original character may be derived.

PLATE VII.

Cliffs formed by rocks of the Nickel Plate formation.

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In general, the division is calcareous throughout, but is divided by bands of quartzite, which vary in thickness from 1 or 2 inches up to 3 or 4 feet. These quartzite bands are not always continuous, and are thicker in certain places than in others. As an example, the quartzite bands are noticeably thicker on the top of the Nickel Plate mountain than they are below the Kingston mineral claim, but in this case it is not absolutely certain whether these are true quartzites or originally calcareous beds which have been replaced by silica derived from a stock of diorite thrust through the beds. When these alternating bands of limestone and quartzite have not been subjected to contact metamorphism, and the bedding planes destroyed, they resemble portions of the Aberdeen formation directly below the Sunnyside limestone.

A characteristic exposure of this phase of the formation is shown in the accompanying photograph, Plate VIII, when bands of dark blue limestone about 6 inches thick alternate with white quartzites of about the same thickness. In the upper portion of this division, both the quartzite and limestone bands are much thicker, showing a longer period of stability between the times of change in sedimentation.

The middle division of the Nickel Plate formation is overlaid, both at the Central station and in Murray cañon, and on Red mountain, by local beds of volcanic material which separate it from the uppermost member of the formation—the Kingston limestone. The normal sequence of sedimentation is seen in Red Eagle gulch, where there are few volcanic beds, and the Kingston limestone directly succeeds the banded rocks of the middle division. Going northward, however, across into Horsefly gulch, not more than 2,000 feet away, thin, dark, reddish layers, presumably volcanic ash material, begin to appear, intercalated in the strata below the Kingston limestone. These layers are taken to be the thinned out edges of the volcanic beds which are so highly developed in Red mountain below the Kingston limestone. It is not possible to trace these beds out continuously to verify this, because a large intrusive stock of diorite intervenes; but if these beds are of the same horizon, it would locate the source of these volcanic materials somewhere to the north of Red mountain.

A satisfactory description of the Kingston limestone is hardly possible, on account of the lack of good exposures, and from the fact that there is no portion of the whole Cache Creek group of the Hedley district that has suffered so much alteration and deformation as this limestone. Over a great part of the area covered by the Nickel Plate formation, it has been completely eroded away, and, where it still remains, it has been folded, faulted, brecciated, or thoroughly silicified, so that its recognition depends almost wholly on its position relative to the other rocks. Perhaps the best exposure is seen in the upper portion of Red Eagle gulch; but here, again, it has suffered so much metamorphism from igneous intrusions that only a general idea of its thickness and original lithological character can be obtained. On its lower side, it has no well-defined bounding plane, and it is only distinguished from the upper members of the middle division of the Nickel Plate formation by its greater thickness.

Megascopically, it is a light grey to dark blue rock, frequently coarsely crystalline, and in places of a loose texture, so that it crumbles readily to a coarse sand. It has not a uniform composition throughout, but contains some thin bands of cherty rock, and others of fine black tuffs. These cherty bands are interbedded with the limestone itself, and were probably formed with it; and are not to be confused with certain irregular cherty masses which occur in the limestone near the contact of diorite, and which are probably due to an introduction of silica from the igneous rock at the time of intrusion.

Like all the rest of the sedimentary rocks, this limestone has a general dip to the west, of from 12° to 30°. On account of its texture and solubility, it has a tendency to form smooth and even slopes and rounded shoulders.

As stated above, it was found impossible to follow out the Kingston limestone in the direction of its strike, because in one direction it has been eroded away, and in the other it has been cut off by eruptive rocks. Northward of Horsefly gulch, diorite has interrupted its continuance for some distance, and when the sedimentary rocks again appear there is difficulty in identifying the Kingston limestone, on account of the metamorphism which it has suffered.

A few hundred feet to the south of Climax bluff a very highly altered band of rock occupies the horizon equivalent to the Kingston limestone. This rock was undoubtedly originally a limestone, but has been metamorphosed and silicified by contact with the igneous rock to the west of it. The metamorphism has taken the form of a recrystallization, and the formation of large crystals of quartz, cal-

PLATE VIII

Alternating beds of limestone and quartzite in the Nickel Plate formation

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cite, garnet, epidote, and some tourmaline and axinite. Where [illegible] has been much weathering, the harder mineral stands out in mar[illegible] relief to the softer. Large prismatic crystals of quartz form a [illegible] work embedded in the calcite. Garnets are well individualized, [illegible] stand out very prominently, while the epidote occurs in bunches [illegible] green radiating fibres. On large outcrops, there is strong evidence of brecciation. This brecciation probably took place before the alteration by contact metamorphism, and is consequently now somewhat obscured by it.

Continuing northward from Climax bluff along a narrow ridge called Windfall ridge, we find a peculiar brecciated limestone, and this, on measuring its height above the well-defined Sunnyside limestone, is found to occupy the horizon equivalent to the Kingston limestone. Where first seen, directly north of the Nickel Plate glory-hole, the breccia bed is made up of angular limestone fragments, varying in size from a few inches to several feet in diameter. These are cemented together with an igneous cement, which, however, forms a very small proportion of the whole rock, but which stands out in marked relief to the limestone. The breccia bed has a distinctly stratified appearance, when viewed from a distance, but when examined in detail, the stratification is not so apparent.

Following the breccia bed along the ridge to the north, the [illegible] material changes from andesitic to calcareous, and we [illegible] remnants of a small band of fine-grained conglomerate inter[illegible] with it. This conglomerate is made up of small rounded [illegible] quartz in a calcareous cement. In weathering, these [illegible] stand out in marked relief, but a fracture often breaks [illegible] across the pebbles, as well as the cement. In places, [illegible] conglomerate appears as narrow streaks not more than 2 inches or [illegible] wide in the limestone, generally, though not always, parallel to the bedding planes of the limestone. The whole occurrence is peculiar and difficult to account for; but, if not due to a metasomatic replacement by silica, may represent an approach to shoreline conditions at the time of the formation of the limestone, but before the brecciation occurred.

From Windfall ridge, the limestone breccia forms a well marked bed, lying on top and below beds of volcanic material, which can be traced right across Red mountain into Bradshaw cañon. The volcanic beds both above and below it are not brecciated, and it is probable that the brecciation of the limestone was effected by hot volcanic rocks alongside it, or the compression and sinking of the loose volcanic tuffs on which it rests.

Beyond, and to the west of Bradshaw cañon, the whole formation is faulted down, and when the Kingston limestone again appears, it is seen to have resumed its normal massive character, and no brecciation is apparent in it. The overlying volcanic materials have also pinched out, and the limestone is directly overlaid by the rocks of the Aberdeen formation. On account of the absence of brecciation to the west of Bradshaw cañon, the belief is strengthened that the brecciation was due to the presence of the accompanying volcanic rocks.

Microscopic Features.—Sections of the massive dark blue Sunnyside limestone show the rock to be made up almost entirely of small grains of calcite. Dark, opaque, probably carbonaceous matter, is distributed through it in such a way as to give an appearance of flow structure to the section. A few quartz grains, hornblende crystals, and some chlorite, as well as some iron oxide, complete the constituents of the section.

The white crystalline limestone which forms the top of the Sunnyside limestone member is seen to be composed of large calcite crystals, with quite a large proportion of quartz grains, showing that the clear-water conditions which prevailed during the deposition of the Sunnyside limestone were gradually changing to the conditions which prevailed during the middle of the Nickel Plate formation, when alternating bands of quartzite and limestone were laid down. Pyrite, pyrrhotite, and iron oxides are sparingly seen in sections of the white limestone.

Unaltered sections of the banded rocks of the middle portion of the Nickel Plate formation are difficult to obtain, and those that we have give little additional information. The siliceous bands, however, are shown by the sections to be of two kinds. One is a typical quartzite made up of small rounded grains of quartz; while the other, which is also found as thin bands in the massive limestone members, is a very fine-grained rock, composed of almost isotropic silica, with a distinctly banded appearance. Associated with this silica are small grains and aggregates of epidote, and a few small crystals of arsenopyrite.

The question of the metamorphism of the Nickel Plate formation is one which is intimately connected with a study of the ore bodies, and as all the known ore-bodies lie in this formation, a detailed description of the metamorphism it has undergone will be deferred to the chapter on economic geology. It will be sufficient to say at this time that, contrary to the findings of some other geologists, it is certain that the impure limestones, and those interbanded with quartzites, have suffered more intense and widespread metamorphism than the purer massive limestone members of the top and bottom of the formation.

RED MOUNTAIN FORMATION.

Distribution.—The Red Mountain formation embraces a considerable thickness of volcanic materials lying in and at the top of the Nickel Plate formation. These attain their greatest development in the long steep ridge locally called Red mountain, which forms a shoulder between Murray cañon and Bradshaw cañon. A smaller detached area of volcanic rocks corresponding to the lower beds of the Red Mountain formation is also found a short distance to the south of Central station. These may originally have been connected with the main body, and later separated by erosion of the connecting portions of the beds, but this is not necessarily so, for the volcanic formation is always a local development, and the rocks of the Central station may have been derived from an entirely different source. The lithological resemblance of the rocks of the two areas, however, points to derivation from a common source. These rocks do not represent a single period of continuous uninterrupted deposition of volcanic materials, but rather two periods, since there is a break about half-way, when the volcanic activity which produced these rocks was arrested, and normal conditions of aqueous sedimentation held for a time. During this period, the Kingston limestone of the Nickel Plate formation was deposited, sometimes on top of the earlier volcanic beds, or where these wedge out, directly on top of the underlying members of the Nickel Plate formation. Consequently, there are in reality two distinct periods of vulcanism represented in the volcanics of the Red mountain and separated by the Kingston limestone. It was thought best, however, to group all these volcanic rocks formed during these two periods under one name, because they are made up of rocks of very similar composition, and were deposited under apparently identical conditions.

There are many other volcanic beds interstratified with the sedimentary rocks, formed at various periods in the history of the Cache

Creek rocks, but they are generally of small vertical extent, and pinch out quickly in a horizontal direction. The rocks of the Red Mountain formation are of much greater thickness than any of these, but like them, are only of local importance, and do not extend far in a horizontal direction, but wedge out quickly in the true sedimentary rocks. As an instance of this, we find in Red mountain a thickness of about 1,000 feet of volcanic rocks; but on following them out to the west and southwest, they quickly decrease in thickness, until, at about 1½ or 2 miles, they die out altogether.

Thickness.—From the foregoing it will be seen that the thickness obtained for this formation will depend entirely on the section across which they are measured. On the upper part of Red mountain, where they attain their greatest development, it has been estimated that they reach a thickness of at least 1,000 feet. Of this about 400 feet lie below the Kingston limestone, and the remainder above. Toward the west and southwest the thickness quickly decreases, until the rocks pinch out altogether. Toward the northeast they appear to increase, but here they have been removed by erosion, or cut off by later igneous intrusions. At Central station the volcanic beds below the Kingston limestone are alone represented, and the thickness of these which now remain is about 250 feet.

Lithology.—The Red Mountain formation is essentially of volcanic origin, and is consequently clearly distinguished from the true aqueous sediments of the other formations. It is, however, treated with the true sedimentary formations, because it is believed that the great bulk of the beds is made up of volcanic materials that were deposited under water in the form of ash or other explosive volcanic ejectamenta. Some undoubtedly true aqueous sediments are intercalated in these beds, but these are of relatively small extent.

The lower portion of the Red Mountain formation, which is most easily studied in the area near Central station, consists essentially of tuffs and breccias, evenly and distinctly bedded and occasionally interstratified with cherty quartzites. A section across these beds shows at the base, beds of breccia of variable thickness and persistency resting on the quartzites of the upper portion of the Nickel Plate formation. The breccias are composed of angular fragments of siliceous and calcareous rocks, interbedded in a tuff matrix, but sometimes cemented together by a calcareous cement. Above these are fine-grained, black and reddish tuffs, with which are interstratified some thin bands of quartzites and argillite, though the volcanic beds greatly preponderate. The reddish tuffs are frequently coarse-grained enough to pass into breccias, and are always highly mineralized with pyrite and arsenopyrite, which are seen in crystals or in small veins. The tuffs are also cut by small siliceous stringers. Higher up the reddish tuffs are replaced by very fine-grained glistening black tuffs, which break with a conchoidal fracture. Above these are porphyritic igneous rocks, conformable with the bedding of the tuffs, dark reddish in colour and difficult to distinguish from the red tuff beds. On the top are more breccias, interbedded with tuffs. The breccias are again made up of angular fragments of limestone, quartzite, and reddish tuffs embedded in an apparently tuff cement; and these beds are sometimes seen to pass by a gradual transition, by decrease in size and number of fragments, into the fine-grained reddish tuffs.

In Red Mountain area the lower beds are very similar to those of the Central station, and consist essentially of reddish tuffs and breccias, and fine-grained black tuffs, interstratified with very thin siliceous bands. These beds are very regularly bedded, and have a thickness of from 15 to 30 feet each. Above the brecciated Kingston limestone, the Red Mountain formation is composed of very hard siliceous fine-grained tuffs, varying in colour from dark to light grey and pale green. These show distinct evidence of stratification, and from the fact that they are interbedded with some quartzite and limestone, were very probably laid down in water. They have been somewhat metamorphosed, with development of slaty cleavage in places. The coarser varieties have a very harsh feel on the fresh fracture, and some of the finer-grained siliceous varieties break with a conchoidal fracture. These rocks contain a great deal of pyrite and arsenopyrite, as well as pyrrhotite, and consequently weather red from the oxidation of the iron. Interbedded with these distinctly clastic rocks are others the mode of origin of which is totally different. These are crystalline igneous rocks of a dioritic composition, fine-grained and dark grey in colour. They are distinctly bedded with the volcanic tuffs, and may be intrusive sheets injected along the bedding planes of the tuffs, or they may be consolidated lava flows, that have been compressed and metamorphosed. They carry an abundant peculiar bluish green hornblende, which is peculiar to these rocks alone, and is not found in any others. Besides hornblende they contain plagioclase, pyroxene, some quartz, and much pyrrhotite.

The upper portion of this formation passes by a gradual transition into the true sediments of the Aberdeen formation above, where the tuffs become much finer in grain, and the beds become gradually thinner and thinner until they are entirely replaced by the quartzite and limestones of the overlying formation.

The upper beds of the Red Mountain formation have a well developed slaty cleavage, which is not found in the more massive beds of the lower part of the formation. This fact appears to be explainable entirely on lithological grounds, the lower beds being more uniformly of a tufaceous volcanic nature, while the upper beds are finer in grain, and the volcanic materials are leavened with a siliceous or argillaceous mixture, which makes them much better adapted to the development of cleavage. A natural concomitant of this is the fact that the lower beds form steep vertical cliffs (see Plate IX), while the upper beds break down readily into small fragments, and form no prominent topographic features.

While the whole formation is very highly mineralized with different sulphides, it has yet to be proved that any of its members are productive in valuable economic deposits.

Structure.—The present attitude of the Red Mountain formation shows little change from its original position, which must have been horizontal or nearly so. There is a fairly uniform dip of about 20° to the west as far as Bradshaw cañon, where the rocks are faulted. When they appear again in the west side of the fault, the dip has increased until the beds are nearly vertical. Beyond this, they quickly die out, though the overlying rocks of the Aberdeen formation preserve this increased dip, far to the westward.

Microscopic Characters.—While the field study of these rocks proves the stratified nature of the beds, the microscopic examination brings out their fragmental origin. The breccias are seen to be made up of angular fragments of different kinds of rocks of various sizes, embedded in a very fine-grained ground-mass. Fragments of glass are very common, which have been somewhat devitrified. Other fragments are made up of an aggregation of small quartz grains, or an indefinite brown biotitic mass. Large crystals of plagioclase, as well as some orthoclase feldspars, with vague indefinite boundaries, are common, as also clear glassy quartz, with rounded or corroded borders. There is much light coloured pyroxene in some sections, occurring in small grains in segregated areas. Frequently, brown

PLATE IX.

Massive beds of the Red Mountain formation.

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biotite of secondary origin has been developed out of the ground-mass, as a result of metamorphism, and some silicification has also taken place. Some samples are cut by many small stringers containing feldspar. Pyrrhotite is everywhere very abundant, and especially in the small stringers. Some arsenopyrite is also present.

The very fine-grained reddish rocks which form such a large proportion of the rocks of this formation are more difficult of study on account of the smallness of the grains of which they are made up. These are made up of three constituents in approximately equal proportions—quartz, feldspar, and biotite. The grains are very small, generally angular in shape, and of a fairly uniform size throughout. The biotite is undoubtedly of secondary origin, and occurs in small crystals or incipient brownish grains, and is so abundant as to control the colour of the whole rock. The quartz and feldspar are difficult to separate from each other, on account of their microscopic size, but are in approximately equal proportion. The feldspars show no twinning, except an occasional Carlsbad twin. Iron ores are rare, and their iron contents may all have gone into the biotite. The rock has undoubtedly been altered by contact metamorphism, but it probably was originally a very fine-grained volcanic ash. It shows no evidence of silicification, except in the case of narrow cherty bands, alongside of which the rock is altered to a very fine-grained compact phase of the normal rock.

Coarser grained varieties of this reddish tuff contain, besides orthoclase and greenish hornblende, some glass fragments somewhat devitrified, all embedded in a very fine-grained ground-mass of a light brownish colour, containing much secondary biotite.

All these rocks give evidence of contact-metamorphism, and of some silicification, so that their original structure and composition is obscured. In general, they vary between rhyolitic and andesitic tuffs.

Conditions of Deposition.—The rocks of the Red Mountain formation are thought to have been deposited under water, and there are several reasons for such a belief. In the first place, the separate beds of volcanic material are evenly and distinctly stratified, though they gradually wedge out toward the west. Again, they are often interstratified with true aqueous sediments, either siliceous or calcareous, and in the case of some of the breccias, the cementing material is a limestone. It would seem as if the whole formation represented a long and almost continuous period of volcanic activity, during which volcanic ash and other materials were blown out from an active vent and deposited in water, interrupting the normal order of aqueous sedimentation. Where there were short periods of quiescence, the normal conditions of sedimentation held, and we find bands of quartzite, limestone or argillite, as indications of these periods. Under such conditions, we should expect to find all gradations between a pure tuff and a pure limestone or quartzite, and such is actually the case. Analogous deposits of this nature are being formed at the present day in the neighbourhood of volcanic islands, and these often abound in organic remains, as in the Solomon islands, the Tonga group, and Torres strait. The absence of organic remains in the Red Mountain volcanic formation does not disprove its deposition in water, because the whole Cache Creek group of rocks is characteristically lacking in fossils.

ABERDEEN FORMATION.

Distribution.—The Aberdeen formation is a distinctly sedimentary formation, embracing all the sedimentary rocks within the limits of the sheet above the upper portion of the Red Mountain formation. Where these volcanic rocks are not represented, this formation rests directly on top of the Kingston limestone. The boundary between the Red Mountain volcanic rocks and the Aberdeen formation is a fairly sharp line, but that between the Kingston limestone and the Aberdeen formation is not so easily identified, on account of the transitional character of the two formations. The upper boundary of the formation is arbitrarily taken as the western boundary of the map, but as rocks of the same character as these extend for a considerable distance outside the map, the term Aberdeen formation is not as restricted as the two preceding formations, and is not intended to be used other than as a local name, and for convenience in describing them. The formation is not a distinct individualized unit, and, therefore, should not be used for purposes of wide correlation.

The Aberdeen formation is the highest portion of the Cache Creek group, found inside the limits of the sheet. It is very extensively developed in the northwestern part of the sheet, on both sides of Twentymile creek, but on account of the attitude in which the rocks stand, the areal distribution is not as large in proportion to its

PLATE X.

Banding in the Aberdeen formation

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thickness as some of the other formations. Its extent is also largely reduced by several intrusions of igneous rock.

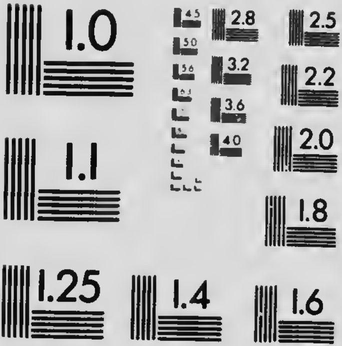
Thickness.—It has been found quite impossible to obtain even an approximation to the thickness of the Aberdeen formation, both on account of the deformation which the rocks have suffered, and the igneous rocks that have intruded them. The beds all stand at high angles, and in the Aberdeen cañon there are exhibited some very close folds, so that in an east and west section across the strike there may be a repetition of strata. Although the formation is made up of beds of different composition, there is a sameness about the way in which these beds are interstratified with each other, which, in conjunction with a change of the same beds by contact metamorphism, makes it difficult to identify any single beds that might occur on either limb of a fold. It is certain that there are at least 3,000 feet of these rocks represented in the map, and if there is no repetition of beds, then twice that amount would not be too much to cover the whole formation.

Lithology.—The lithological characters of the Aberdeen formation have not been studied in great detail, but except that there is not such a relatively large proportion of siliceous beds, the main characteristics are very similar to those of the Redtop formation. In the lower portion of the formation there is a somewhat larger proportion of volcanic beds than is found higher up, due probably to the gradual diminution of the volcanic activity, which was at its height during the deposition of the Red Mountain formation. In this lower portion we find white quartzites interbanded with fine-grained black tuffs. Above this are interbanded limestones and tuffs, in bands of a few inches in thickness. Higher still we find the tuffs to have almost disappeared, and blue limestones and white quartzites are interstratified together in bands which gradually increase in thickness. In ascending the strata, these last mentioned conditions hold for many hundreds of feet in beds that dip at very high angles.

Nearly 3,000 feet up in the formation these conditions still hold, and in Aberdeen cañon, thin bands of blue limestone are interstratified with white quartzite, with the limestone preponderating. Occasionally, intercalated with them, are found thin bands of fine black tuffs or beds of volcanic breccia, generally only a few inches in thickness. The smaller of these bands are in many places seen to continue only for a short distance, and then to die out between the

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



layers of quartzite or limestone. These volcanic beds indicate that occasional outbursts of volcanic activity were still taking place, but that the effects were not far-reaching, and their limits are frequently recorded in the exposed beds of this formation. These tuffs weather to a rusty brown or red from the iron content, and they are very hard and siliceous, breaking with a conchoidal fracture. They contain a great deal of mica in fine scales, which are well-developed along cleavage or joint planes. The breccia beds contain only small fragments 1 inch or less in diameter, and indicate a greater distance from the source than the breccia beds of the Red Mountain formation.

With regard to the microscopic characters of these rocks, there is little to be said in addition to what has already been said of similar rocks in either the Redtop or Nickel Plate formation. On the whole, the quartzites and argillites show somewhat less silicification by secondary actions than was evinced by the rocks of the Redtop formation. Except near eruptive igneous masses, where contact-metamorphism has been at work, the argillites are less siliceous, and the quartzites less cherty, and probably not so abundant. The volcanic rocks also are finer in grain.

The whole formation does not contain any large beds of quartzite, limestone, or other rocks, but is made up of alternating beds of different rocks, rarely more than a foot or two in thickness, and generally somewhat less than that. The characteristic appearance of the formation is well shown on the face of Stemwinder hill, overlooking the town of Hedley, where the rocks have a beautifully banded appearance, due to alternating shades of black and dark blue, to light green and white, the darker shades being produced by tuffs, argillites, or limestones, while the cherty quartzites give the lighter.

Rapid and sudden changes in deposition is the characteristic feature of the rocks of the Aberdeen formation. Occasionally a change in the beds might indicate an oscillation of level, and a change from deep sea to nearly shore-line conditions; but often the change is from a true aqueous sediment to a volcanic rock, denoting an explosive outburst of volcanic activity, and the rapid deposition of volcanic materials from this source.

Structure.—The present attitude of the rocks of the Aberdeen formation shows a much greater tilting and deformation than any of the underlying formations. The whole formation stands either in a vertical attitude, or is very highly inclined, and while there is little to indicate any large folds, so as to give a repetition of beds, many minor folds, closely compressed, are exposed in parts of Aberdeen cañon. This is characteristic of all the upper portion of the Cache Creek group for several miles outside the map to the west. The compression which these rocks have undergone has not developed any well marked slaty cleavage, except in the argillaceous rocks in isolated portions outside the map, and here the cleavage developed is parallel to the bedding plane.

The topographic forms dependent on these rocks show nothing characteristic or prominent. In places, however, where they have been altered and silicified by contact metamorphism, some prominent bluffs are formed.

While these rocks occasionally show some mineralization, no productive ore bodies have yet been discovered in them within the limits of the map. Outside and to the west, mining development shows some indications of silver ores occurring, and particularly where these rocks become much more argillaceous.

CORRELATION AND AGE OF THE CACHE CREEK GROUP.

In the subjoined table, an attempt is made to compare the portion of the Cache Creek group of the Hedley area with the typical rocks of this age described by Dawson in the Kamloops map sheet. It must be borne in mind, however,, that the total thickness of 6,300 feet found in the Hedley district, does not represent the total thickness of Cache Creek rocks in this region. The base of the Cache Creek group in the Hedley sheet is not exposed, as the lowest member is here seen to be a massive limestone, which is truncated by a batholithic intrusion of granodiorite. In the same way, the uppermost beds, which are called in the table the Aberdeen formation, of which the minimum thickness is given as 3,000 feet, simply represent the amount of these beds that appears within the limits of the map. It is known that beds conformably overlying these extend for some 3 miles to the west, outside the sheet, when they are also truncated by a batholithic intrusion of granodiorite. The attitude of these beds outside the sheet is, as a rule, about vertical, and it is very probable that a section across them would not represent their total thickness, but something more, for the same beds may be many times repeated in closely folded anticlines and synclines. It is impossible, therefore, to get even an approximation to the total thickness of these rocks as originally represented in this portion of the Similkameen district. The figures given in the table as the total thickness, then, merely represent the amount of Cache Creek rocks occurring within the limits of the Hedley map.

In placing these sedimentary rocks in the Cache Creek group, it must be confessed that the author is simply accepting Dr. Dawson's conclusion of over thirty years ago. In his report of explorations made in 1877, in referring to these rocks at Hedley, he says, [1] 'They may be taken as representing the Cache Creek group, and are referred by analogy to the same age'—that is, the Carboniferous. He also makes mention of finding fossils in the rocks, a short distance above the mouth of Ashnola river, 8 miles below Hedley. These fossils were minute, branching tabulate corals, and the rocks in which they occur, precisely resemble lithologically those elsewhere found in association with quartzites, which hold Carboniferous fossils. The rocks to which he here refers lie about 6 miles to the southeast of the Hedley sheet, but are not found inside this sheet. They probably represent, however, higher beds which are conformably above those of the Hedley sheet, and which at one time covered them, but have since been removed by erosion.

No new palæontological evidence to substantiate Dr. Dawson's conclusions has been obtained in the field work of the last two years. The only fossil found has been that of a badly crushed and quite indeterminable brachiopod in a bed of breccia. The correlation, then, of these rocks, is based entirely on lithological characters, but the similarity to proven Cache Creek rocks no farther away than in the Kamloops map sheet, is so striking that correlation on these grounds alone must bear some weight.

The massive limestones of the upper part of Dawson's Kamloops section have no counterpart within the Hedley sheet, or even in the country immediately adjoining. His middle division, consisting essentially of volcanic materials with lesser quantities of limestones, argillites, and cherty quartzites, with a minimum thickness of 2,000 feet, might well be represented by the two upper series of the Hedley column. There is a considerable difference in the relative thickness, but that can readily be accounted for—and indeed is to be expected—by local accumulation of volcanic material in certain sections. On the other hand, his description of the sedimentary beds intercalated between the volcanic materials, could be applied almost

[1] Report of Progress, 1877-78, p. 87 B.

without change to those occurring in that part of the Hedley column. This portion of the column in both regions is characterized by a great preponderance of volcanic materials over the true sedimentary rocks.

Dawson's lowest division, which was originally called Lower Cache creek, consists of cherty quartzites, argillites, volcanic materials, and limestones, in about the relative order of importance in which these are named. The corresponding beds in the Hedley map, while containing all the different kinds of sediments mentioned, with the exception of serpentine, perhaps vary somewhat in the relative importance of these components. Cherty quartzites are the most abundant members in the Kamloops section, whereas in the Hedley section, limestones appear to preponderate in the upper parts; while lower down, the Redtop formation is characterized by a much greater development of quartzites, accompanied by siliceous argillites and volcanic materials—the latter locally. The minimum thickness of this part of the Kamloops section is given as 4,500 feet, whereas not more than 2,100 feet of the beds supposed to correspond to these are found in the Hedley sheet. The disparity, however, is readily accounted for by the fact that the bottom of the Hedley section does not appear, having been truncated by eruptive rocks of a batholithic nature.

The data for correlation of these rocks is undoubtedly meagre. The use of parallel columns, however, serves to bring out the striking lithological resemblance between them, and suggests a similarity of conditions prevailing at the time of deposition of the beds. Both columns indicate many, and sometimes long continued periods of volcanic disturbance, and frequent changes in sedimentation on the sea floor. These features appear to be characteristic of Cache Creek rocks wherever found in central and southern British Columbia.

Rocks which have the lithologic characteristics of the Cache Creek group have been described by G. O. Smith, as occurring on the south side of the International Boundary line in the lower part of the Similkameen river. These are not now connected with the Hedley rocks, being separated by eruptive rocks, but they may represent contemporaneous sedimentation in Carboniferous times along the western side of the British Columbia Pre-Cambrian axis.

HEDLEY SECTION.	KAMLOOPS SECTION.
	3. Massive limestones with minor intercalations of volcanic rocks, quartzites, and argillites . . . . 3,000 ft.
4. *Aberdeen Formation*: quartzites, limestones, siliceous argillites and volcanic material. . . . . 3,000 ft. +	2. Volcanic materials, limestone, with some argillites and cherty quartzites. . . . . 2,000 ft.
3. *Red Mountain Formation*: essentially volcanic materials, with some limestone and quartzite. . . . . 1,200 ft. + or	
2. *Nickel Plate Formation*: essentially limestone, with some quartzite bands. . . . . 900 ft.	1. Cherty quartzites, volcanic materials, argillite, serpentine, and limestone. . . . . 4,500 ft.
1. *Redtop Formation*: cherty quartzites, siliceous argillites, volcanic materials, with some limestone bands. . . . . . . 1,200 ft. Base not seen.	

DIORITE GABBRO.

GENERAL STATEMENT.

This is a composite formation made up of a variety of rocks ranging in mineralogical composition between a quartz diorite at one end and a gabbro at the other. The quartz diorite, however, and the gabbro make up the bulk of the formation; while the other varieties are relatively much less abundant, and are merely differentiates from one or the other, or transitional between them. These two main types are not exactly contemporaneous in age, but the difference between them is so slight that the older quartz diorite was not thoroughly solidified before the gabbro was erupted through it. They are, consequently, very intimately associated with each other, and for this reason, and on account of their evident consanguinity, they are classed together under one head. An attempt is made in the colour scheme of the geological map to indicate the geographical distribution of these two main types, but the result is not very satisfactory, on account of the indefinite nature of the contacts.

DISTRIBUTION.

The distribution of the rocks of the formation is indicated on the geological map, and a glance at this will show that they lie mainly in the northwest quarter of the area, and on either side of the deep narrow cañon of Twentymile creek. They occur in three distinct stock-like masses, and in several intrusive bodies of very irregular form, as well as in a great number of apophyses from these larger bodies. The two large areas to the west are simple stocks, each due to a single intrusion of the diorite, while that on the east of Twentymile creek, on account of its being made up of separate intrusions of the two main types, is more correctly designated a composite stock. A smaller elongated body of gabbro, having some of the characteristics of a stock, as well as that of an injected body, makes up the prominent knob called Climax bluff, and forms the steep cliffs running northeastward from there.

All of these bodies are very irregular in outline, but the contacts with the older sedimentary rocks are generally well exposed, and can be accurately delineated wherever the topography will allow access to them. These contacts are often exposed deep enough to suggest a downward enlargement of each of the separate stocks, and as the distances by which they are separated from each other on the surface is not great, it is not unlikely that they would be found to unite below into one large stock; and that the portions now exposed are merely the unroofed portions of the upper surface. Further erosion would, therefore, tend to increase the areal extent of this formation.

In their intrusion through the older sedimentary formations, the rocks of the Hedley diorite-gabbro cut across the strata, and send off a great number of apophyses, parallel to bedding planes of the sediments, as well as across them. The tilting of the sedimentary formations upwards toward the east, and subsequent erosion of the upturned edges, has exposed a large number of these apophyses on the eastern slope of Nickel Plate mountain. For the same reason, much fewer of these apophyses are seen on the western slope. Many of the apophyses from the diorite gabbro bodies were mapped, but many more occur which are not shown on the geological map, partly because they are small and irregular, and partly on account of the impossibility of tracing them out in the very rugged portion of the region in which they occur.

The distribution within the stocks themselves, of the various types of rock which together make up the whole complex is not easy to state very specifically. Quartz-diorite has the greatest areal distribution of all the types represented. It forms the main central portions of the three large stocks lying in the northwestern portion of the district, and is also found in some of the larger irregular bodies in this section. It does not occur in the apophyses from these stocks, except to a very limited extent in the larger ones where they join the stocks.

Diorite is, as a rule, found to be a border phase of the quartz diorite, that is to say, it appears on the outer border ot the quartz diorite where this is in contact with the older rocks. It also makes up some of the smaller irregular projections from the stocks, such as that which runs off to the north by Aberdeen station. An elongated dike-like body which lies to the west of Bradshaw cañon, near the top of Aberdeen ridge, is made up of a quartz mica diorite.

In apophyses which have been given off from the diorite stocks, and which are very abundant in the vicinity of these stocks, the rock is a diorite porphyry. This phase of the complex is confined to the apophyses, and to only those apophyses which originated from the diorite portions of the stocks. These apophyses are most abundant in the region about the head of the gravity tram-line, but they are also found peripheral to all of the other stocks of diorite in the district.

Gabbro has not a wide areal distribution, and is almost entirely confined to the central portion of the district or the region centreing about Climax bluff. In the southernmost of the three stocks, namely, that into which the Horsefly gulch is cut, cores of gabbro are surrounded by quartz diorite. Larger bodies of gabbro lie on the northern border of this stock. The most important area, however, is the elongated body which makes up Climax bluff and the steep cliffs running northeast from here for about 2,200 feet.

Porphyritic forms of the gabbro make up the apophyses which have been given off from the larger bodies, and these are most abundant on the Nickel Plate mountain about the Sunnyside mine. They are, however, not confined to the periphery of the plutonic gabbro masses, but are also sometimes found far away, in which cases they are always closely associated with the diorite phases of the complex.

In a general way it may be said that gabbro and gabbro porphyry only form about one-tenth of the total area covered by the diorite-gabbro complex. Quartz diorite covers perhaps seven-tenths; while the remainder is occupied by diorite, diorite porphyry, or transitions between diorite and gabbro.

LITHOLOGICAL CHARACTERS.

Macroscopic.—The various kinds of rocks which together make up the diorite-gabbro complex, show considerable differences in appearances, as well as in mineralogical composition. When studied in the field, it was found impracticable to differentiate sharply between the various types on account of the transitions between them, and the lack of clearly defined contacts. There are, however, two main types which form the extremes in composition of this complex, and when these alone are compared, without the transitional forms, the contrast is marked; but when these transitional forms are included, a complete series is formed, which has no sharp line of division. At one end of this series is a quartz diorite, which passes easily into a normal looking diorite having no quartz at all. At the other end is a pale greenish white gabbro. The quartz diorite and the gabbro have the greatest areal distribution, while the intermediate forms are relatively less abundant.

The distinction between the two main types, that was made in the field, depends partly on colour and partly on mineralogical composition. The one is a medium (millimetre grained), light grey to dark coloured rock, generally normal looking quartz diorite, but with a variable proportion of the dark constituents in different areas. It contains two kinds of feldspar, black hornblende, and some quartz. In the field, and in a previous summary report, it was called a monzonite, but more detailed chemical and microscopic study proves that quartz diorite is a more appropriate name.

A basic phase of the quartz diorite is found, to a limited extent, in certain portions of the stocks, and more particularly on the outer borders. Such a rock shows a lack of quartz and a very marked increase in the proportion of hornblende present, becoming thereby a typical hornblende diorite. At times the hornblende becomes so abundant that it controls the colour of the rock. The accompanying plagioclase is correspondingly decreased, and the result is an almost black granitoid rock. This occurs either in ill-defined areas on the outer border of the quartz diorite, or else it forms streaks or 'schlieren' in the quartz diorite.

The second main type of the complex is the gabbro, which occupies small areas in or alongside the quartz diorite. It is a very pale greenish to almost white rock, of equigranular texture and medium coarseness. It consists essentially of plagioclase, and very pale greenish pyroxene (diallage). Its general appearance is suggestive of a much more acid composition than it actually proves to be. In the hand specimen, its chief points of difference from the quartz diorite lie in its light colour, the absence of quartz and hornblende, and the presence of pyroxene. It frequently forms ill-defined contacts with the quartz diorite, as if intrusive into it, sending off at the same time many narrow tongues into the quartz diorite. There is also a slight blending of the two rocks on these contacts, but only over a very narrow zone. In this zone are found minerals in association with each other, which are peculiar to both types of rocks. It frequently happens that on the contact of the quartz diorite with the older sedimentary rocks, not only is a normal hornblende diorite formed, but a rock which appears to be transitional between quartz diorite and gabbro. This is a rock of lighter colour than the diorite, but slightly darker than the gabbro, and the hand specimen show an abundance of light green pyroxene, and some black hornblende.

Apophyses from the stocks, both from the diorite and gabbro portions of them, have everywhere thrust themselves into the older sedimentary rocks, and generally along the bedding planes as being the lines of least resistance. In these, while it is common to find a development of porphyritic structure, this is not always an essential feature. In general, diorite apophyses have a porphyritic structure developed in them by an enlargement of the hornblende crystals, but on approaching the stocks this structure is lost and they take on the granitoid structure characteristic of the stocks. The diorite apophyses are more basic than the quartz diorite in that they contain no quartz whatever. They correspond in mineral composition more nearly to the hornblende diorite phase of the stocks, than the quartz diorite.

As in the granitoid forms, there is a gradual transition from diorite to gabbro in the porphyritic forms. In the gabbro apophyses, porphyritic structure is not so commonly seen; but the rock takes on a finer grain, and the two main constituents—plagioclase and pyroxenes are not so sharply differentiated. The transition to the diorite porphyry is marked by the appearance of large phenocrysts of black hornblende embedded in the gabbro mass. These become more abundant as one goes toward areas of typical diorite porphyries until the gabbro characteristics are lost altogether.

The mica diorite of Bradshaw canon is an isolated type, and is not found in any but this one intrusion. In the hand specimen, it has characteristics which appear to associate it with the younger granodiorite, but it is more likely a special differentiate of the diorite-gabbro magma. It differs from the quartz diorite in having no quartz, but contains biotite as well as hornblende, as an essential constituent. These two minerals, with plagioclase, make up the components of the rock. Its structure is not eminently porphyritic, nor is it typical granitoid, but while all the crystals are of visible size, the three essential constituents tend to develop as phenocrysts in a ground-mass, which is made up of small grains of the same minerals.

Microscopic.—In discussing the petrography of the diorite-gabbro rocks, some method is necessary to avoid confusion or repetition. A six-fold division suggests itself as the most convenient and natural method of treatment, and all the important variations will be included in one or the other of these six heads. These will be, therefore: (1) quartz diorite; (2) diorite; (3) diorite porphyries; (4) gabbro; (5) gabbro porphyries; (6) transition forms.

Quartz Diorite.—This rock occurs only in plutonic form in the stocks, and occasionally in the largest apophyses near the stocks. A typical specimen, such as the one obtained from the base of Stemwinder hill, and the one whose chemical analysis is given farther on, shows a rock of light to dark grey colour and medium grained granitic texture. The dominant feldspar is plagioclase, with the composition of andesine, and determined as $Ab_{55}An_{45}$. Zonary structure is characteristic of it, showing that there is variation in composition in different zones of the same crystal. The crystals show a tendency to idiomorphic outline, and some exhibit a slight twisting and bending, which give a wavy extinction to the crystal. The alteration of the plagioclase is not great, but small flakes of mica are developed in it. Orthoclase is present as an essential constituent in variable proportions. It is less idiomorphic than the plagioclase, and slightly more decomposed. A rim of orthoclase around a core of plagioclase is occasionally seen. Quartz is always interstitial, and in clear glassy irregular grains it forms sometimes as much as 15 per cent of the whole rock, but usually less.

Green hornblende is the most abundant coloured constituent, and is always greatly in excess of the biotite, which is never more than an accessory mineral. There is, however, a mutual relation between the two, and the biotite generally occurs included in or adjacent to the hornblende. A tendency to parallel arrangement of the hornblendes seen in the hand specimen is not evident in the thin section. The hornblende is idiomorphic toward the other constituents, and was the first of the essential constituents to crystallize out. It shows no evidence of being secondary in origin, nor any tendency to alteration to other minerals. The flakes of brown mica, however, frequently exhibit a rim of secondary magnetite.

Of the accessory constituents, titanite is the most abundant, in characteristic wedge-shaped crystals. Calcite, which appears sparingly in the fresh rock, is apparently a primary constituent, and has been reckoned as such in calculating the norm of the rock. Other accessories are magnetite, arsenopyrite, epidote, and zircon.

A chemical analysis of the quartz diorite from the Stemwinder hill has been made by M. F. Connor in the laboratory of the Mines Branch, Department of Mines. The following is the result:—

SiO_2	58·36
Al_2O_3	18·38
Fe_2O_3	5·53
FeO	5·30
MgO	2·60
CaO	7·20
Na_2O	3·15
K_2O	1·98
H_2O+	0·80
H_2O-	0·10
CO_2	0·13
TiO_2	0·54
P_2O_5	0·12
MnO	0·14
SrO	trace
BaO	0·10
	99·43

By calculation of the norm of this rock, according to the method of Cross, Iddings, Pirsson, and Washington, we get the following:—

Quartz	= 10·68 per cent		
Orthoclase	= 11·68		
Albite	= 26·72		79·10 Salic.
Anorthite	= 30·02		
Diopside	= 3·50 per cent		
Hypersthene	= 13·59		
Ilmenite	= 0·91		
Magnetite	= 0·70		19·31 Femic.
Apatite	= 0·31		
Calcite	= 0·30		

$\frac{Sal.}{Fem.} = \frac{4·09}{1}$	Class II	Dosalane
$\frac{Q}{F} = \frac{1}{6·4}$	Order 2	Austrare.
$\frac{K_2O+Na_2O}{CaO} = \frac{1}{1·4}$	Rang 2	Alkalicalcic
$\frac{K_2O}{Na_2O} = \frac{1}{1·59}$	Subrang 3	Sodipotassic

This rock, therefore, is harzose. For the purpose of comparison with the norm, the mode or actual mineralogical composition was recalculated from the chemical analysis, and with the help of some microscopic determinations. The proportion of albite to anorthite in the plagioclase molecule was first determined from the thin section, and, from a large number of measurements, the ratio of Ab to An was found to be 55 to 45. The percentage of biotite was then determined by the Rosiwal method, and found to be 2·26. Enough K_2O and other constituents were taken out to make up this percentage of a biotite with average chemical composition, and after allotting the proper number of molecules to make up the minerals known to occur, the remainder was calculated as hornblende, with the excess of silica as quartz The following result obtained by this method is fairly close to the average mineralogical composition, and is checked by the Rosiwal method:—

Quartz	9·48	
Orthoclase	10·56	
Plagioclase	48·40	(andesine)
Hornblende	26·51	
Biotite	2·26	
Titanite	0·98	
Magnetite	0·46	
Apatite	0·31	
Calcite	0·30	
	99·26	

This mineral composition shows the rock to be a quartz diorite of a normal kind.

Diorite.—The quartz diorite rock is the most common and constant variety in the stocks. Variations, however, are noted in different portions of the same stock, and these variations depend on the relative proportions of the different constituents. Quartz is a very variable constituent, and to a certain extent the proportion of orthoclase varies with it. Occasionally the quartz disappears altogether, but some orthoclase always remains, and the rock becomes a normal diorite. Biotite is fairly constant, but merely as an accessory, the proportions of which seldom exceed 2 per cent of the rock. Hornblende and plagioclase are always essential, the former varying in amount in different parts of the district and of the same stock.

The most basic form of the dioritic rocks is found in the extreme northwest portion of the district, at the western end of Aberdeen ridge. This, in the hand specimen, is a very dark, almost black rock. Under the microscope it shows no quartz whatever, and only a small amount of orthoclase. Plagioclase is abundantly present, but the amount of hornblende is very greatly increased over the amount present in the quartz diorite. The structure is distinctly poikilitic, with idiomorphic laths of plagioclase feldspar entirely enclosed in large crystals of dark green hornblende, the portions of which fill the spaces between the feldspars, but are all parts of one large crystal and extinguish together. Magnetite is more abundant than in the quartz diorite, and as before, often occurs as a secondary rim about the small flakes of biotite that are present. Some arsenopyrite is present as an accessory constituent.

Diorite Porphyries.—Apophyses from the dioritic portions of these stocks have penetrated widely the older sedimentary rocks. These are more of the nature of sheets injected into the bedding planes of the strata, but cross-cutting apophyses are also common. As might be expected from the position of the stocks, and the way in which the strata dip into them from the east, the greatest number of these apophyses are on the east of the stocks, and on the eastern and southern slopes of Nickel Plate mountain. From their iron content these apophyses always weather to a dark red colour, and often form prominent ridges. Different dikes of this rock vary considerably in size, and are found up to 50 feet in thickness; but individual dikes are remarkably uniform in size, and are very persistent. In

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Banding of the sedimentary rocks due to injected sheets of porphyritic diorite.

typical examples of these, the structure is porphyritic except where they approach the parent stock, and here the structure becomes gradually more granitic. The phenocrysts are invariably long black hornblendes and plagioclase feldspars. These feldspars are basic andesine in composition and frequently show zonal structure. They are always idiomorphic, and of variable size, passing gradually into the feldspars of the ground-mass. They show some alteration due to decomposition, and are irregularly fractured, and in the vicinity of the granodiorite contact there is metamorphism, due to this contact. The hornblendes are long and lath shaped, and show no transition in size to the hornblendes of the ground-mass. They are generally fresh, but occasionally show some alteration to chlorite. The ground-mass is holo-crystalline, and made up of small laths of feldspar and hornblende, and shreds of brown mica. Some orthoclase is present in the ground-mass. Accessory minerals are titanite, arsenopyrite, pyrrhotite, and some quartz, the sulphides being usually quite abundant. The titanite is in small grains or wedge-shaped crystals associated with the hornblende. Pyroxene is entirely wanting. From this undoubted genetic connexion and mineralogical similarity to the diorite of the stocks, these apophyses are properly termed diorite porphyries.

An isolated phase of the dike forms of the diorite is a porphyritic mica diorite found cutting sedimentary rocks to the west of Bradshaw cañon. It cannot be connected directly with the diorite of the stocks, but it has characteristics which associate it with the diorite. In the thin section, it shows three essential constituents—plagioclase, hornblende, and biotite. The plagioclase is andesine, occurring in large crystals with rounded outlines, frequently strained and sometimes broken. Biotite is in brown crystals also strained and bent, while the hornblende is green in colour and in large crystals less abundant than the biotite. The structure is slightly porphyritic, with a ground-mass composed of grains of plagioclase, orthoclase, biotite, and hornblende, enclosing the three larger constituents. The ground-mass appears to have suffered considerable deformation, and by the crushing and granulation of its constituents during intrusion, a protoclastic structure has been developed.

Gabbro.—The later phase of the diorite-gabbro composite stocks is a gabbro which is thought to be merely a product of the same magma as the diorite, but erupted after differentiation has taken place. The rock in the hand specimen is almost white in colour, and of granitoid texture. Typical examples of this rock are obtained from the western face of Climax bluff, and from the upper portion of the composite stock to the north of the Kingston mineral claim. From the latter place, samples were taken for petrographic study, as well as for chemical analysis.

The thin section of the gabbro shows the rock to be made up of only two essential constituents—plagioclase feldspar, and pyroxene. The plagioclase has been determined as labradorite of the composition Ab_2An_3, and forms about 56 per cent of the whole rock. It shows a slight zonary banding, with a more acid feldspar on the outer border. The crystals are well developed, and show a peculiar irregular fracturing. They also exhibit a slight tendency to parallel arrangement of their longer axes. They are slightly turbid, indicating a certain degree of alteration. Their whole structure is hypidiomorphic.

The pyroxene is almost colourless, or has a pale greenish colour, and forms about 39 per cent of the whole rock. It appears in large tabular crystals of typical augitic habit, giving extinction angles in the neighbourhood of 45°. The crystals all have good prismatic cleavage, with occasionally a parting dividing the angle of cleavage. They are always fresh, and show no decomposition or alteration to other minerals. In spite of its strongly augitic habit, its chemical composition, as determined from the chemical analysis of the rock, is very similar to the chemical composition of a diallage described by Dana as occurring in gabbro at Ehrsberg.[1]

The Hedley pyroxene, as shown by the rock analysis, is marked by a total absence of F_2O_3 and a fairly high per cent of Al_2O_3, and from this composition it can only be called a diallage, but one of augitic habit. The chemical composition as computed, is as follows:—

SiO_2	51·35
Al_2O_3	6·57
FeO	9·28
MgO	11·77
CaO	21·09
	100·06

Of the other constituents of the gabbro, orthoclase is sparingly present, and quartz is absent. Titanite is very abundant as an acces-

[1] Dana's System of Mineralogy, p. 360, No. 55.

sory in small wedge-shaped crystals and grains. Apatite forms large thick crystals, and some primary calcite is found in some sections.

The following chemical analysis of the gabbro was made by M. F. Connor in the laboratory of the Mines Branch of the Department of Mines:—

SiO_2	= 51·08
Al_2O_3	= 19·77
Fe_2O_3	= trace
FeO	= 3·60
MgO	= 4·57
CaO	= 16·03
Na_2O	= 2·56
K_2O	= 0·28
H_2O+	= 0·65
H_2O-	= 0·15
CO_2	= 0·32
TiO_2	= 0·45
P_2O_5	= 0·14
MnO	= 0·09
SrO	= trace
BaO	= trace
	99·69

Calculation of the norm, according to the method of Cross, Iddings, Washington, and Pirsson, gives the following percentages of the different constituents:—

Quartz	= 0·06 per cent.	= 64·91 Salic.
Orthoclase	= 1·67 "	
Albite	= 21·48 "	
Anorthite	= 41·70 "	
Diopside	= 28·37 "	= 33·86 Femic.
Hypersthene	= 3·72 "	
Apatite	= 0·31 "	
Ilmenite	= 0·76 "	
Calcite	= 0·70 "	

$\frac{\text{Sal.}}{\text{Fem.}} = \frac{1·91}{1}$ = Class II .... Dosalane.

$\frac{\text{Q.L.}}{\text{F.}} = \frac{1}{10·81}$ = Order 5............ Germanare.

$\frac{K_2O + Na_2O}{CaO} = \frac{1}{5·99}$ = Rang 4............ Docalcic.

$\frac{K_2O}{Na_2O} = \frac{1}{9·14}$ = Sub-rang 3............ Presodic.

According to the above classification, the rock is, therefore, a hessose.

Owing to the simplicity of its mineral composition as seen under the microscope, a recalculation of the mode or actual mineralogical composition is a simple matter, after the pr... of ...ite to anorthite in the plagioclase has been accurately determined. This proportion is found by a number of measurements to be 40 to 60. All the Na_2O is then allotted to the albite, and a sufficient amount of CaO to the anorthite, to make the above proportion. After taking out the apatite, titanite, and calcite, all of which are known to occur in the rock, the remainder is calculated as pyroxene, the proportion of RO to SiO_2 being almost exactly 1 to 1. The actual mineral composition as computed by this method, is as follows:—

Orthoclase	=	1·67
Plagioclase { Ab = 21·48, An = 34·75 }	=	56·23
Diallage	=	38·88
Apatite	=	0·28
Titanite	=	0·98
Calcite	=	0·71
		98·75

Plagioclase and pyroxene together make up about 96 per cent of the whole rock. Though of such simple mineral composition, no rocks of exactly similar chemical composition could be found in Washington's compilation of superior analyses.[1] Both the high percentage of CaO and the absence of Fe_2O_3 make it rather abnormal. The nearest approach in composition to it is a gabbro described by H. W. Fairbanks, from Point Sal, Santa Barbara county, California.[2] G. O. Smith has also described a gabbro from Beverley creek, Kittitas county, Washington, which is somewhat similar in composition.[3] The analyses of each of these rocks, however, show a lower percentage of SiO_2 and CaO, but a higher percentage of MgO and total iron. The megascopic characters of the Beverley Creek rock are also somewhat similar to the Hedley gabbro.[4] Smith describes it as a rock of light grey to greenish or purplish colour, and composed of basic labradorite and diallage, with some hornblende and magnetite.

Gabbro Porphyries.—The dike forms of the gabbro are, like those of the diorite, apophyses from the parent stock, and they appear both as sheets in the bedding planes of the sediments and as cross-cutting bodies. In distribution they are less abundant than the diorite rocks, and are more restricted in area. They are found most abundantly on the Nickel Plate and Sunnyside mines, where some

[1] U.S.G.S. Prof. paper 14.
[2] Bull. Dept. of Geol., Univ. Cal., p. 50, 1896.
[3] U.S.G.S., folio No. 106, p. 6.
[4] Ibid.

attain a thickness of 100 feet or more. They are always closely associated with the ore deposits, and are, therefore, of great economic importance.

Mineralogically, the gabbro apophyses are identical with the rock of the stocks, with often the development of a porphyritic structure. In the hand specimen the rock is white, and often fine-grained, and from its hardness forms bold outcropping ridges between the bands of sedimentary rocks. The thin section shows generally a porphyritic structure, with phenocrysts of feldspar and pyroxene in a fine-grained but crystalline ground-mass. The feldspars are labradorite with the characteristic zonal structure. The pyroxene is white or very pale greenish, and is in broad tabular idiomorphic crystals identical with the pyroxene of the stocks, which is a diallage. These pyroxenes are often crushed and fractured, and are at times, in the neighbourhood of the ore bodies, entirely replaced by potash-feldspar, or by calcite. In the case of replacement by feldspar, the resultant mineral is made up of a number of small grains which together form a pseudomorph after the pyroxene. The ground-mass is fine-grained, and made up of small crystals of plagioclase and grains of light coloured pyroxene, with some titanite, and much sulphide mineral, which is generally arsenopyrite. Most of the thin sections studied show a notable amount of metamorphism, particularly of the pyroxene. Some silicification is also evident near the ore bodies, but no primary quartz is ever seen.

Transition Forms.—Transitions between a diorite and a gabbro, both in the plutonic and porphyritic forms, were noticed in the field, and microscopic study confirms the conclusions there formed. In the plutonic forms, this transition was noticed particularly on the outer border of the diorite stocks, where differentiation by basification had taken place. Thin sections of these show a slightly finer grain, with the femic materials more highly developed than the salic. The feldspar is labradorite in long lath-shaped crystals, idiomorphic toward the other salic minerals. Orthoclase is present in a small and variable proportion. Quartz varies with the orthoclase, and may be present or not. If present it is in small irregular crystals filling interstices between the other minerals. Among the femic minerals, hornblende is the more abundant, but occasionally pyroxene forms the larger proportion. When in the ascendancy, hornblende forms large elongated crystals, while the pyroxene is in small tabular grains. When the pyroxene is more abundant, it occurs in broad tabular crystals of a white or very pale green colour, without sensible pleochroism. Biotite is generally present as an accessory, and when most abundant is found moulded onto the hornblende. When pyroxene increases the biotite decreases, like the quartz. The usual accessory minerals are present here also, and there is much sulphide mineral, either pyrite or arsenopyrite.

In the porphyritic forms, transition types intermediate between gabbro and diorite are occasionally found. Those types which are more nearly related to the gabbro show a ground-mass identical with that of the typical gabbro porphyry; but besides the labradorite and pyroxene phenocrysts, there are large elongated phenocrysts of black hornblende, scattered sparingly through the rock, generally inches apart from each other. As the type approaches the composition of the diorite porphyry, the hornblendes increase in quantity, and thin sections of these show phenocrysts of both hornblende and pyroxene, with the labradorite embedded in a fine-grained ground-mass, composed of feldspar and pyroxene grains. Quartz as a primary constituent is entirely wanting in all the sections. Arsenopyrite is often very abundant as an accessory constituent in well formed crystals.

Metamorphism.—From external agencies, the rocks of the diorite-gabbro formation have suffered little metamorphism. The effects produced on its internal structure by regional orogenic movements have not been very marked, and are discussed in a later section. Tho contact metamorphism which has been induced in it by the intrusion of the granodiorite through it is also very light, and not to be compared with that which this rock had induced in the stratified rocks. A good contact between the granodiorite and the diorite can be seen on the Metropolitan mineral claim on the eastern slope of the valley of Twentymile creek. Here the contact is a sharp line, and what metamorphism there is in the diorite is very slight, and not apparent to the unaided eye.

The contact metamorphism which it has suffered in its own body by reason of intrusion through older rocks has already been referred to, and need only be briefly mentioned here. The effect on the diorite has been a slight basification along the contact, and the formation of pyroxene in addition to hornblende, with the complete elimination of quartz. The presence also of some lime silicate at the immediate contact might indicate the absorption of some material from the sedimentary rocks. In the case of the gabbro, no such basification was noticed, but a very evident silicification on the contact of quartzite by the absorption of some of the quartz is a phenomenon very noticeable in thin sections of the contact rock.

The most marked metamorphism is seen in the gabbro apophyses, where the · have been intruded into the sedimentary rocks, and where ore bodies have been formed. This metamorphism takes the form of a replacement of the pyroxene of the gabbro by secondary feldspar and by calcite. The secondary feldspar is here an unstriated potash feldspar, always clear and fresh. It occurs in small grains, replacing the pyroxene crystals by attacking them from the outer border and projecting inward. In the early stages of this process, there is often seen a core of pyroxene surrounded by a ring of small feldspar crystals, all pointing inward toward the centre of the pyroxene. When this process has been completed the result is a pseudomorph after pyroxene composed of an aggregation of feldspar grains. In other instances the secondary feldspar develops irregularly through the pyroxene crystals, so that a sort of poikilitic structure is developed. The same feldspar fills fissures which traverse the gabbro. These are always minute, and are not apparent except under the microscope.

In the same manner as the feldspar replacement, calcite also replaces pyroxene and fills small fissures in the gabbro. The source of the calcite is apparent, and is undoubtedly in the sedimentary rocks into which the gabbro has been intruded. The presence of the alkali feldspar, however, is not so easy of explanation, but it is probably connected with certain phenomena following the intrusion of the gabbro apophyses.

STRUCTURAL RELATIONS.

Internal.—The internal structure, so far as it can be referred to differentiation, or the relation of one type to the other, has been partly discussed under a previous heading, but it will be as well to state all the evidence here, even at the risk of repetition.

As previously stated, there are two main types of rocks in the complex—a quartz diorite and a gabbro. The former composes the bulk of the complex, and occupies the main central portions of all three stocks, while the latter is in smaller volume, either in the same stock with the quartz diorite, or alone. Where the two occur in the same stock, and are in contact with each other, a great number of narrow tongues of gabbro are found projecting into the quartz diorite, and ramifying through it. The contacts, however, are not sharp, but show a decided blending of one rock with the other, giving just such an effect as might be expected if the gabbro were intruded into the quartz diorite before the latter had thoroughly solidified. Such contacts indicate an intrusion of the gabbro, slightly later than the quartz diorite.

Within its own mass the quartz diorite shows considerable variation in mineral composition in different parts of the same stock. This is not so much a difference of kind as a difference in the relative proportions of the same minerals. Such differences never result in the formation of a more acid rock than the quartz diorite, but they always tend to produce a rock slightly more basic, and approaching the composition of the gabbro. Such differences are most marked, also, on the older contacts of the quartz diorite, and in the apophyses which have originated from the stocks. While the contacts of the quartz diorite show a thorough transition to gabbro over a distance of an inch, or a few inches, there is also a longer, but just as complete a transition through their apophyses, which gives the same result. Starting with the quartz diorite of the stock on the east side of Twentymile creek, we find that, on approaching the southern border of this body, quartz diminishes in quantity. Entering one of the apophyses, the quartz disappears altogether, and the rock has become a diorite porphyry. Numbers of these porphyry dikes can be found crossing the electric and gravity tram-lines near the upper ore bin, and many of them can be traced directly by their outcrops into the parent stock. Passing next along the electric tram-line northward from the head of the gravity tram-line to the Nickel Plate mine, a complete transition can be marked in the different dikes crossed from diorite porphyry to gabbro porphyry. This transition is not continuous by one dike alone, but is apparent in passing from one dike to the other. The change is effected by a gradual disappearance of the hornblende of the diorite porphyry, and the appearance of pyroxene in its place, both in the phenocrysts and in the ground-mass, until the rocks of the Nickel Plate mine have the mineral composition of the gabbro without any hornblende whatever. These last rocks are apophyses from the stock of gabbro which forms Climax bluff.

The gabbro itself, where it appears as cores in the quartz diorite, or as isolated bodies, is generally uniform throughout, and shows no tendency to differentiate to more basic forms. It appears rather to be itself the final femic product of differentiation of the diorite-gabbro magma, of which the quartz diorite is the salic pole. That the progress of differentiation was from acid to basic, is shown by the fact that the gabbro is intrusive into the quartz diorite, and is, therefore, a later rock. Again, in the dike forms of these rocks, the gabbro porphyries are not always confined to the borders of the gabbro stocks, but ... found long distances away. In such cases, however, ... ways close ... associated with diorite masses. In contrast to ... are ... the gabbro, the dike forms of the diorite are alwa... associated ... with the massive forms or stocks of this roc... ver ... pear on the periphery of the gabbro as differentiatio... of the gabbro. The conclusion one might draw is that the ... is a later differentiation product of the original magma ... gave rise ... diorite.

It is very evi... that the two main types of this complex are closely related, not only in ... ogical composition, but in mode of origin. The relations ... to the other appear to show that they were ... th deriv... the same magma, and one probably intermediate in composition ... ween the two rocks. Also, that after the processes of ... magma chamber had advanced to such a stage that the ... was more or less stratified into a quartz dior... ove, and ... below, the top layer cooled somewhat more ... dly ... solidified. Before complete solidification, however, the lower ... magma was forced up through the pasty crust of quartz ... ve the conditions as we now have them.

The internal structure ... diorite-gabbro complex, so far as it is dependent on exter... agencies such as mountain building, is an easier study, and of a less theoretical nature. The apophyses of these rocks generally lie parallel to the bedding planes of the old sedimentary rocks into which they have been thrust, and where these show folding and crumpling, the igneous rocks show a similar structure. Either the igneous rocks were thrust into the sediments when they were lying in a horizontal undisturbed position, and afterwards elevated and folded together; or it is possible that the sedimentary rocks were first folded, and the igneous rocks were afterwards thrust into them, following along the bedding planes of the folded sedimentary rocks as the lines of least resistance. The evidence at hand is not sufficient to solve the problem, but it is more than likely that the folding may have had a genetic connexion with the igneous intrusion, and that the two events are not separated by any great length of time.

It is certain that these rocks have been subjected to all of the faulting that is now evident in the rocks of this district. No faulting appears to have affected the Carboniferous sediments without affecting the diorite-gabbro rocks, but much of this has not affected the later granodiorite. Fissuring is also apparent in the number of small stringers of feldspar that traverse these rocks everywhere. These are always small, and are occasionally mineralized with arsenopyrite, but the mineralization is never enough to form ore bodies of even doubtful value. Evidence of deformation is also to be obtained from a study of the thin sections. In these, a slight straining and bending of the feldspar crystals, accompanied by granulation of the ground-mass, is frequently seen. No schistosity, however, has been developed, though there is occasionally a tendency toward it in the parallel arrangement of some of the hornblendes. Some shearing is seen, and altogether these rocks have undoubtedly passed through some rather severe orogenic disturbances.

External.—(a) Relation to Older Formations.—Evidence illustrative of the relation of the diorite-gabbro complex to other formations is never lacking, and contacts are very common. Particularly apparent is its relation to the Cache Creek sediments. These contacts show the intrusive relation of the complex, and the way in which dozens of sheets and dikes from it have penetrated into and across their bedding planes. At the same time the metamorphism that has been induced in these sediments is extreme, and they show striking evidence of alteration at and near the contacts. The limestones have been most altered, and by the expulsion of the CO_2 and the substitution of SiO_2, the carbonates have been altered to silicates, with the formation of such minerals as garnet, epidote, diopside, tremolite, wollastonite, and axinite. The impure limestones show much more contact metamorphism than the pure massive forms. The contact in the massive forms is rarely a clean-cut line, and there is evidence, by the inclusion of some of these lime silicates in the diorite-gabbro near the contact, that there has been some assimilution of the sedimentary rocks. The contact metamorphism in the sediments, besides showing alteration to lime silicates, very often takes the form of dense grey siliceous masses of irregular outline and variable size.

Often, also, the silicification has confined itself to certain bands, and in these the resultant rock is fine-grained and cherty, and composed largely of chalcedonic silica.

Accompanying the formation of lime silicates in the contact metamorphic zone, there has been at the same time an introduction of sulphides from the diorite-gabbro complex. These sulphides are arsenopyrite, pyrrhotite, chalcopyrite, sphalerite, and pyrite, and their intergrowth with each other, and with the lime silicates, shows an almost contemporaneous formation. Contrary to what might be expected, the gabbro has apparently been more effective in inducing contact metamorphism, and in mineralization, than the diorite.

While the gabbro shows, as a rule, much the same kind of indefinite contact with the sediments as the quartz diorite, it also forms, in some places, a brecciated contact. In such cases there is a narrow zone of brecciation a few feet wide, where highly altered fragments of the sedimentary rocks are cemented together by igneous material, soft, friable, easily weathered, and with a ropy structure. These contacts suggest locally a different mode of intrusion to the others.

(b) Relation to Younger Formations.—A well-known contact between quartz diorite and granodiorite appears on the Metropolitan mineral claim. It is noticed here that the granodiorite sends off apophyses into the quartz diorite, and often holds fragments of the latter in its own body. Again, many contacts show the granodiorite truncating sheets of diorite porphyry, which are interbedded with the sedimentary rocks. In all cases, however, the metamorphism induced in the quartz diorite is relatively insignificant.

No contacts of gabbro with the granodiorite are ever seen, but an example of a small roof pendant of sedimentary rocks, in which is a dike of gabbro, resting on and completely surrounded by granodiorite, is sufficient to establish the relative age of these two rocks.

The diorite-gabbro andesite rocks are also known to be cut by lamprophyre, keratophyre, and rhyolite dik

MODE OF ORIGIN.

The nature of the intrusion of the diorite-gabbro complex is shown in many exposures of its contacts with the older sedimentary rocks. These exposures show by the size, evenness of grain, and mineral association of the component crystals of the gabbro diorite, that it solidified under deep-seated conditions. The physical relations to the older rocks show that the magma did not make room for itself by thrusting aside the sediments, for they do not now show any evidence of dislocation from these intrusions. Contacts which show the diorite-gabbro rocks cutting directly across the bedding planes of the sediments, though they have induced much metamorphism in the sediments, indicate that the uniformity of the dip of the strata has not been disturbed on their edges. The action of intrusion, therefore, appears to have been quiet and gradual, and similar to that recorded on the contacts of many batholithic masses. The areal extent of the diorite-gabbro rocks in the district is not great in any one of the three main masses exposed, so that they are properly designated by the term stocks. The horizontal distance, however, which separates these masses, in all cases is so small that we might be justified in presuming that they would all be united into one main body at no great distance below the surface.

The mode of origin of the gabbro portion of the stocks is not so clearly expressed in its contacts as that of the quartz diorite. Where it cuts sedimentary rocks, it is true it exhibits a vertical or highly inclined contact with an even more indefinite contact line than the quartz diorite forms; but it frequently also shows a brecciated contact zone for short distances, as if it had here forced a way for itself through the overlying sediments. A good exposure of its contact with the sedimentary rocks at Climax bluff shows the characteristic vague contact zone. Here the intruded rock is a quartzite. The gabbro itself is an almost white rock, and in passing over the contact, it is impossible to say, within several yards, where the igneous rock begins, or the sedimentary ends. The two appear to merge into each other. The thin section too, brings out this blending of the two rocks by a mingling of constituents, for while the normal gabbro contains no quartz whatever, it is seen here to carry much quartz in a sample which was taken a short, but undetermined distance away from the contact, in what was thought megascopically to be normal gabbro. In the intrusion of this rock, therefore, it looks as if there might have been forcible injection of molten rock along a passage which it made or enlarged for itself, and this was accompanied by some assimilation of the intruded rocks.

The contacts with the quartz diorite do not throw much light on the method of intrusion of the gabbro. The contact has already been described as a transition one, with numbers of small apophyses from the gabbro, projecting into the quartz diorite, and blending with it, all tending to show that the quartz diorite was still in an unsolidified pasty condition at the time of the gabbro intrusion. In this case, the exposures now seen must then have been at considerable depth, and the forcible injection of the gabbro into the quartz diorite would leave no evidence of such an injection on the quartz diorite, for this rock would readily adjust itself to the position into which it was thrust, and there solidify later.

AGE AND CORRELATION.

The question of the age of the diorite-gabbro complex is one which is attended with much difficulty and obscurity. Evidence has been cited for the belief that the quartz diorite and gabbro are closely connected in origin, and in time of irruption, so that in attempting to fix their age they may be considered together.

We know the relative age of these rocks, namely, that they are younger than the Cache Creek sediments, and older than the granodiorite, but the date of the latter intrusion is also uncertain, as there are no later sediments to which it can be referred. There remains, therefore, merely the structural features by which to assign the age.

Orogenic crushing, and consequent metamorphism, does not seem to have affected these rocks very largely, and certainly not to the extent of developing any schistose structure, or much shearing. That they have undergone some such movement, however, is shown by the fracturing and granulation exhibited in the thin sections, and by the straining and bending of some of the crystals. Megascopically, too, fracturing is seen in the small narrow fissures with which the rock is traversed. Faulting, also, on a large scale has taken place since the intrusion of these rocks. There are two periods recorded in the history of rocks, later than Carboniferous, in this part of British Columbia, when intense orogenic disturbances took place[1]—one about the close of the Jurassic, when the Cache Creek sediments were uplifted and folded, and another at the close of the

[1] R. A. Daly, Bull. G. S. A., vol. 17, pp. 326-376

Laramie, when the Cretaceous rocks of the upper Similkameen river were crushed and folded. It is not likely that these rocks could have passed through both of these periods without showing more evidence of it, but it is tolerably certain that they have been affected by one such period of disturbance, and that presumably the latter one, namely the post-Laramie disturbance. It is, therefore, inferred that the time of irruption of these rocks should be placed in a time somewhere between the close of the Jurassic and the end of the Laramie. They are consequently called Mesozoic, without attempting to further restrict their age.

GRANODIORITE.

DISTRIBUTION.

The rocks described under this head, and indicated on the map by one colour, are generally uniform throughout, and show little variation in petrographic characters. The portion appearing on the map forms only a small fraction of a large batholith which extends outside the area to the east and south, and many miles to the west. Within the limits of the Hedley district these rocks attain their greatest exposed development in the southern half of the sheet, and if they were not covered by the recent stream deposits of the Similkameen river and Twentymile creek, would be found to have a still wider distribution than that shown.

This is the latest consolidated formation in the district, and cuts all the others. From its mode of origin, and the way in which it is seen to underlie the sedimentary rocks on the slope of the Similkameen valley, it is to be expected that its underground development will be much greater than that shown on the surface, and it may be found to form the floor on which most of the other rocks of the district rest.

In the southwest portion of the district, it occupies the lower portion of the Similkameen valley, and underlies all the other formations. In the southeast portion its contact, rising suddenly from the lower portion of the valley, cuts directly across the overlying sediments, and passes outside the district to the east at about the 4,500 ft. contour line.

Genetically connected with the main batholith of granodiorite is a dike-like body of similar rock extending from Eighteenmile creek in a direction N 30° W across the shoulder of the mountain, and down to the bend in Twentymile creek, about a mile above the town. This body is nearly 2 miles long, has an average width of about 450 feet, and is almost perfectly straight. It apparently follows one of the main lines of weakness in the district, and one that coincides with the trend of Twentymile creek in that portion above the first bend.

LITHOLOGY.

Macroscopic.—The normal rock of the granodiorite is light coloured and medium grained (millimetre grained) in texture. It is made up of two kinds of feldspar and quartz, with hornblende, or biotite, or both. The dike-like body appears uniformly to carry biotite in excess of the hornblende, but in the main body the proportion is more equal, with generally hornblende predominating. It shows very little surface weathering, and is generally fairly fresh on the outcrop. On this account, it breaks along its joint planes into huge blocks, and forms talus slopes of these blocks, unlike the slopes of any other formation. Where it does weather down it forms a coarse pinkish sand, easily distinguished from the soil overlying limestone or diorite. It contains many rounded or oval-shaped basic segregations, and is frequently traversed by small veinlets of feldspar or quartz.

Microscopic.—Unlike the diorite-gabbro formation, the granodiorite is fairly uniform in texture and composition throughout all parts of its body, except the immediate contact phase. A single specimen of a fresh rock selected from the main body would, therefore, be fairly representative of the whole formation. Under the microscope, such a section shows a very fresh rock which has undergone little decomposition or deformation. It is made up of plagioclase, orthoclase, quartz, hornblende, and biotite as the essential constituents.

Plagioclase is the most abundant constituent, and is an oligoclase in composition. It is usually twinned polysynthetically, after the albite law, and is generally idiomorphic toward the orthoclase. The crystals are large, broad, and fresh, and show very little alteration. Zonary banding is very characteristic of the plagioclase, and individuals with a basic centre become slightly more acid toward the outer border. Orthoclase is much less abundant, and is generally slightly turbid from decomposition and the formation of small flakes of mica throughout the crystals. There is a frequent intergrowth of the orthoclase with quartz, resulting in micrographic structure.

Quartz is less abundant than the feldspars. It always has irregular outlines, and occurs in interstices between the other constituents, being the last to form. It is always clear, fresh, and glassy, and extinguishes sharply.

Hornblende alternates with biotite in being the more abundant ferro-magnesian mineral. In the main body of the granodiorite it is in excess of biotite, but in the large granodiorite dike the reverse is true. The hornblende is dark green, and pleochroic, and idiomorphic toward the quartz, feldspars, and biotite. Biotite is dark brown, and also strongly pleochroic, and frequently shows a rim of magnetite. It appears in shreds and flakes, which are occasionally bent and altered to chlorite.

Of the accessory minerals, titanite is most abundant, in its characteristic wedge-shaped feebly pleochroic crystals. Other accessories are small grains and crystals of apatite, zircon, magnetite, and pyrite.

A chemical analysis, by M. F. Connor, of a typical specimen showing biotite slightly in excess of hornblende, gives the following results:—

SiO_2	= 62·08
Al_2O_3	= 17·91
Fe_2O_3	= 1·08
FeO	= 3·08
MgO	= 1·17
CaO	= 4·54
Na_2O	= 5·12
K_2O	= 2·96
H_2O+	= 0·20
H_2O-	= 0·05
TiO_2	= 0·54
P_2O_5	= 0·17
MnO	= 0·11
SrO	= trace
BaO	= 0·14
	99·77

Calculation of the norm of this rock, according to the method of Cross, Iddings, Pirsson, and Washington, gives the following percentages:—

Quartz	8·22 per cent.		
Orthoclase	17·79 "		
Albite	42·97 "	85·94 Salic.	
Anorthite	16·96 "		
Diopside	3·90 "		
Hypersthene	6·57 "		
Ilmenite	0·91 "	= 13·31 Femic.	
Magnetite	1·62 "		
Apatite	0·31 "		

$\frac{Sal}{Fem} = \frac{6 \cdot 38}{1}$ = Class II............Dosalane.

$\frac{Q.L}{F.} = \frac{1}{10 \cdot 67}$ = Order 2............Germanare.

$\frac{K_2O + Na_2O}{CaO} = \frac{1 \cdot 75}{1}$ = Rang 2............Domalkalic.

$\frac{K_2O}{Na_2O} = \frac{1}{1 \cdot 73}$ = Sub-rang 2............Dosodic.

The rock, therefore, is akerose.

From a thin section of the rock, the actual mineral composition was determined by the Rosiwal method. On account of the difficulty of quickly separating orthoclase from plagioclase, because the latter often shows no albite twinning, the two were classed together, and calculated as total feldspar. The result is as follows:—

Quartz	= 12·91 per cent.
Feldspar	= 71·00 "
Biotite	= 7·28 "
Hornblende	= 5·80 "

It is possible, by combining the results obtained by the Rosiwal method and the chemical analysis, to make a re-calculation which probably will give us within one per cent the actual mineral composition, including the orthoclase and plagioclase feldspars. By taking the analysis of a common variety of biotite, and allotting enough K_2O in this proportion to make up 7·28 per cent of biotite, and leaving the remainder to go to form orthoclase, we get the following mode of the essential constituents:—

Quartz	= 12·91 per cent.
Orthoclase	= 14·45 "
Plagioclase	= 59·55 "
Biotite	= 7·28 "
Hornblende	= 5·80 "

According to the Rosenbusch classification of rocks, the rock is a granodiorite, but one belonging to the basic end of the series, and almost a quartz diorite.

Comparison of this rock with the quartz diorite shows a very close relationship between them. In the younger granodiorite there is a higher percentage of SiO_2, Na_2O, and K_2O, and a corresponding lower percentage of Al_2O_3, FeO, and MgO. The younger rock is slightly more siliceous and alkaline. It follows, also, that the quartz and orthoclase of the mode are higher.

Metamorphism.—The amount of metamorphism, either regional or contact, undergone by the granodiorite, is very limited indeed. There is a slight decomposition and alteration visible in the thin sections of the feldspar constituents, and a slight straining and bending of the biotite flakes, but, apart from this, the rock is almost perfectly fresh. As it is the latest large igneous intrusion in the district, and it is only cut by small trachyte dikes, it has suffered no contact metamorphism whatever.

STRUCTURAL RELATIONS.

Internal.—The most interesting and evident feature of the internal structure of the granodiorite is that of differentiation, which is exhibited on some of the outer borders of the batholith. While the body of the rock is remarkably uniform throughout, and of a normal character, there is frequently a marked change on its contacts with the older rocks. Figure 2 is an actual section of the contact of the granodiorite batholith with the Sunnyside limestone, and the upper beds of the Redtop formation. This section is exposed on the northern side of the Similkameen valley, and it is wholly uncovered, except for a few feet at the very base, so that it can easily be mapped and studied.

In passing upward from the normal granodiorite at the base, toward the contact of the Sunnyside limestone near the western end of the section, a change in the character of the granodiorite becomes apparent, at a distance of about 30 feet from the contact. In other places along this contact the change takes place at 50 feet, or even more. Here it is noticed that the dark minerals, hornblende and biotite, become less abundant, and gradually disappear, until 15 feet away from the limestone none are visible in the rock. The rock then becomes light pink in colour, and very feldspathic—features which it preserves up to the contact. Within 2 feet of the contact, a slight change in texture takes place and the rock is noticeably more siliceous. Here a porphyritic structure is developed

Talus of granodiorite blocks.

with phenocrysts of quartz embedded in a fine-grained groundmass of pinkish white feldspar. Numerous small seams and stringers of clear white quartz traverse the rock in this zone, and higher up in the apophyses. The actual contact with the limestone shows about 2 inches of a perfectly white, fine-grained rock, soft but so compact that the different constituents cannot be identified by the eye. Above this is the sharp clean-cut line of contact with the limestone, showing no blending whatever of the two rocks.

Apophyses of the same character as the contact phase of the granodiorite, which are later described under the head of aplites, penetrate the overlying sediments at various points along the contact. These are also of a light pink colour, and contain only two visible constituents—quartz and acid feldspar. They exhibit very similar characteristics to those of the contact zone, namely, the development of a porphyritic structure within 2 feet of the contact, and a soft compact white band at the immediate contact. On following these apophyses out and away from their source, there is a marked tendency in them to become more and more siliceous, until they pass into very siliceous quartz porphyries. These apophyses, like the contact zone, are cut by many small stringers of white quartz.

Though chemical analysis of the rocks of this contact is lacking, a study of the field relations, which are always very well exposed, shows that there is a strong tendency in the granodiorite to differentiate on its *upper* contact to a rock which is more siliceous and much more feldspathic, while the femic minerals remain below in the undifferentiated rock. This differentiation indicates an upward rise of silica, and the alkalis to form quartz and feldspar, and a sinking or remaining behind of the iron, magnesia, and lime which go to make up the femic constituents.

Differentiation on such a scale is not exhibited on the contact of the large 400 ft. dike of granodiorite which runs diagonally across the shoulder of Nickel Plate mountain. This also sends out apophyses of aplite laterally into the adjacent rocks, but they are fewer in number and smaller in size. The contacts with the quartz diorite on the one side, and the sediments of the Nickel Plate formation on the other, are sharp, well-defined lines, and in the hand specimen there appe[illegible] to be little if any change in texture or composition of the granodior[illegible], and certainly no development of a contact zone of aplite.

Reasons for the development of a wide aplitic contact zone in the one case, and an entire lack of it in the other, are obtained from a study of the form of the igneous body and its underground extension. In the case of the granodiorite dike, it is the lateral contact which is now seen, for the dike stands vertically and the roof has been eroded away. The contact exposed in the Similkameen valley, on the other hand, is a roof contact. Not only is the contact in the Similkameen valley almost horizontal for nearly a mile, as shown in the section, but, when it comes to the transverse valley of Twenty-mile creek, it turns directly at right angles and is found to run almost horizontally in this direction for several hundreds of feet, until it is covered by the gravel deposits of this stream. If the upper surface, therefore, of the granodiorite batholith were exposed, it would be found to be an almost flat, or at least not greatly tilted plane. The formation of the aplitic zone, therefore, on the almost flat upper surface of the batholith, could be explained by a trapping on this surface by the roof of sediments, of the lighter, siliceous and alkaline portions of the magma before it solidified. Some of this would find its way by cracks and fissures into the sediments of the roof to form the apophyses; but the heavier femic minerals remain below. Lateral contacts, such as those exposed on the border of the large dike, or even where the contacts of the main batholith steepen, do not show this aplitic border, because the light minerals which constitute this phase have probably risen beyond to the roof.

A characteristic feature of the granodiorite, in contrast to the other igneous rocks of the district, is the presence of many small rounded or oval-shaped areas of dark basic material, which at first sight appear to be inclusions; but since they are seen under the microscope to contain only constituents which are essential to the granodiorite, it is more likely that these are merely differentiation products, and due to the segregation of the femic minerals in certain areas. These segregations are very abundant, and vary in size from 1 inch up to 4 inches in diameter. This, however, is a feature which is common to many granitic rocks, not only here but elsewhere.

The granodiorite shows little evidence of having undergone orogenic disturbance, and exhibits no brecciation, either microscopically or in the field. Neither has it suffered any faulting. Small fissures, a fraction of an inch in width, which have become filled with quartz or feldspar, and contain also some sulphide mineral,

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Figure 2

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traverse it everywhere, and appear to represent cooling cracks in the chilled rock, which were soon filled with material emanating from the cooling magma.

Joint planes have been developed in the rock, so that it breaks readily in four main directions. These have a bearing of 50°, 75°, 180°, and 295°, only the last of which bears any relation to the direction of the strongest fractures in this region.

External.—The granodiorite is known to cut every rock formation in the district, except the andesite dikes, and these also cut the granodiorite. Its contacts are, as a rule, well exposed, so that no doubt can be entertained of its relations to the other rocks. These contacts are generally sharp, and show no tendency to transition from one rock to the other. Its contact with the sedimentary rocks is well shown in a natural section exposed on the northern slope of the Similkameen valley, and is illustrated in the accompanying illustration, Fig. 2. This section shows the sedimentary strata, with the included sheets of diorite porphyry dipping to the north at angles of 25° to 30°, and truncated by the eruptive grandiorite.

It is difficult to estimate the amount of contact metamorphism that has been induced in these sedimentary rocks [illegible] the granodiorite, for we know, from comparison, that [illegible] of metamorphism must have already been induced in [illegible] intrusion of the diorite-gabbro and its apophyses. It is [illegible] r, that the granodiorite must have had a great influence [illegible] g about the result that now obtains in these sediments. It [illegible] ced here, as in the case of the diorite and gabbro contacts, that the banded sediments, whether quartzite, limestone, or tuffs, show much more alteration than the massive limestones. In the former, there appears to have been an introduction of silica, often in a chalcedonic form, and which may have gone to form the lime silicates, while in the latter, there has merely been a crystallization of calcite near the contact, without the formation of any lime silicates.

A slight mineralization accompanies the granodiorite on these sedimentary contacts, but it is relatively insignificant, when compared with that which accompanies the gabbro, or even the diorite contact.

The metamorphism induced in the massive diorite formation is very slight indeed. The effect seems to have been much greater in the dike forms of the diorite, where they occur as sheets in the sedimentary rocks.

Comparing the total amount of contact metamorphism effected by the granodiorite with that effected by the diorite-gabbro rocks, we are immediately struck with the fact that the metamorphism has been much greater on the borders of the stocks of gabbro and diorite and their apophyses close to these stocks, than it has been on the granodiorite contact. This is all the more strange, because the mass of the granodiorite is many times greater than that of all the diorite-gabbro stocks put together. Not only so, but the chemical composition of the granodiorite is so much more acid than that of even the most acid phase of the diorite-gabbro, that we should expect greater contact metamorphism on the contact of the former than the latter.

The difference is due probably to physical rather than chemical factors. The field relations of the granodiorite show that we actually have the roof of a batholith here exposed, and that the contact we now see is one which has only been exposed by the deep erosion of the Similkameen valley. It is probable that by the time the granodiorite magma in its upward course reached its present position it had lost a great deal of heat, and was slowly solidifying, losing, at the same time, its power to metamorphose the overlying rocks. That it was also becoming viscous is shown by the small number of apophyses which it sends off into the sedimentary rocks overlying it. In the diorite-gabbro magma, on the other hand, we only have the lateral contacts, and the magma must have had enough superheat to penetrate upwards, much beyond the exposures which we now see, and these contacts must have been exposed to greater heat than the roof contacts of the batholith. The diorite-gabbro magma also was much more fluid, and greater fluidity would indicate greater heat, or the presence of more water or mineralizers. The greater fluidity is shown in the great number of its apophyses, the ease with which they penetrate the sediments, the distances which they travel, and the uniformity of thickness of any one apophysis over great areas. Many of these apophyses are only a few inches thick, but they persist, in spite of their thinness, for greater distances than the largest of the granodiorite apophyses. On the hypothesis, therefore, of greater heat and fluidity, and the presence of more abundant mineralizers, it is possible to account for the greater power of metamorphism of the diorite-gabbro rocks over that of the granodiorite.

MODE OF ORIGIN.

The origin of the granodiorite is analogous to that of the diorite-gabbro already described, and differs only in its greater size. While the diorite-gabbro rock has been properly designated as occurring in stocks, the granodiorite is more correctly described as a batholith. If the amount of granodiorite shown on the geological map represented its total areal extent, it could hardly be called by this name; but it is known to cover a great many square miles of territory outside the limits of the map. Its contacts—and particularly those seen in the valley of the Similkameen river—show the nature of its irruption. Plate XI shows the granodiorite lying at the base of the hill with the older sedimentary rocks lying on top of it, and dipping at an angle of 25° into it. It is impossible to conceive from this contact that this irruption could have taken place by any simple process of injection, without leaving abundant evidence of general disorder in the sediments above. These rocks, however, appear to be quite undisturbed by this irruption, and retain the dip and strike which they had before. The irruption, therefore, must have been slow and gradual in its action, and this contact seems to illustrate very well the theory of magmatic stoping advanced by Dr. R. A. Daly[1] and Barrell[2] for batholithic intrusions.

The contact shows that the granodiorite lies underneath the sediments all along the slope of the valley, and passes around the shoulder of the hill, and up into the valley of Twentymile creek. A cross section of this would show that the upper surface of the granodiorite, on which the sediments rest, is almost flat, or dips downward to the north at a very low angle. We have, therefore, the actual roof of a batholith here exposed, and one that froze before it reached the surface, and has only since been exposed by erosion. From the total extent of this batholith, both inside and outside the district, and from its exposed contacts, we are almost justified in supposing that it underlies a great part of the rocks of the Hedley district at and below the level of the Similkameen river. The great extent of this body suggests replacement, rather than simple injection, and its downward enlargement is shown for some distance. The internal structure and crystallization of the batholith indicate that it cooled before reaching the surface, and its contact has only been laid bare by the erosion of the Similkameen valley.

It is not absolutely certain whether the large dike of granodiorite which extends from Eighteenmile creek across to Twentymile creek

[1] Mechanics of Igneous Intrusion, A. J. S., vol. 26, p. 17, 1908.
[2] U.S. Geol. Surv., Prof. Paper No. 57, 1907.

has a similar origin or not, but it is thought, from its following one of the main lines of weakness in the district, that its origin is more of the nature of an injection along this line of weakness. This dike follows the same line as one of the main reaches of Twentymile creek, and while no faulting or displacement is apparent in the Twentymile valley there is some evidence of a slight displacement in the part of the line occupied by the dike. The conclusion drawn from a study of this dike is that the fracture was formed before the eruption of the granodiorite, and when this event did happen, a portion of the magma was thrust into this line of weakness to form the dike.

AGE AND CORRELATION.

As in the case of the diorite-gabbro complex, only the relative age of the granodiorite is known with certainty. We know that it follows the diorite-gabbro in point of time, but there are no younger rocks the age of which is definitely known, until we come to the glacial deposits. Structural features are again the only grounds on which any estimate of age can be based. These are, however, generally of a negative character. The rock has apparently suffered very little from orogenic disturbance, and in the thin sections no straining, brecciation, or granulation is apparent. Gneissic structure is also entirely wanting. The fact that the dike-like mass of this rock has been thrust into a plane of dislocation suggests that this dislocation must have taken place prior to the intrusion of the granodiorite. This dislocation and disturbance is referred to the period of orogenic disturbance at the close of the Laramie, and, therefore, the granodiorite irruption must be at least post-Laramie in age.

Batholithic intrusions of granite, granodiorite, and other igneous rocks have been carefully studied by Dr. R. A. Daly, on the International Boundary line, about 20 miles to the south of this district, and these are all united into one composite batholith with a width of 60 miles.[1] Certain of the members of this composite batholith have been referred by Dr. Daly to a period later than the post-Laramie deformation, and while they may be totally different in composition to the granodiorite here described, it is probable that they may be referred to the same period of batholithic intrusion.

[1] R. A. Daly, Bull. G. S. A., vol. 17, pp. 326-376.

DIKE ROCKS.

Lamprophyres.—The lamprophyres of the district are dark, fine to medium grained rocks, found only in small dikes, which are rarely over 3 feet in width. They are composed essentially of feldspar and idiomorphic crystals of hornblende or augite, with or without a fine-grained ground-mass. The trend of the dikes is not uniform, but varies through an arc of 60°, that is to say, from N 75 E to S 45° E. They occupy tightly closed fissures, and while some of them are known to occupy fault planes, others fill subsidiary fissures which have a tendency to parallelism with the fault planes. They are not remarkable for their persistence, either in extension or in direction.

On account of their small size, and the readiness with which they decompose they are not conspicuous in the topography. Some are found in the underground mine workings which are concealed on the surface by drift. The majority of these dikes were found to the east and northeast of Climax bluff, and all within a radius of three-quarters of a mile. They are mostly found cutting the sedimentary rocks. A few were found cutting the gabbro and diorite stocks, but none are intrusive into the granodiorite.

The lamprophyres show considerable variation in megascopic appearance. A common type is a fine and even-grained rock, showing abundant crystals of feldspar, and either hornblende or pyroxene. In other specimens, both the ferro-magnesian minerals and the feldspar show a decided porphyritic structure, which is most marked in the hornblende-bearing rock. In these the ground-mass is very fine and almost aphanitic.

The microscope shows these lamprophyres to belong to two distinct types—a kersantite and a camptonite, one in which hornblende and biotite are the dominant femic minerals, and another in which pyroxene holds that position. The essential constituents of each of these types are plagioclase, hornblende, and biotite in the one case, and plagioclase and pyroxene, with subordinate hornblende and biotite, in the other case. Some orthoclase is generally present in each of these types, and in the former, quartz is sometimes a subordinate constituent.

Plagioclase is the most abundant constituent in all the rocks, both as phenocrysts, and in the ground-mass. Hornblende or augite is second in importance. The biotite when it is present is found only rarely as phenocrysts, but usually in the ground-mass in small flakes, where it is relatively abundant. In sections where pyroxene occurs, it takes the place of hornblende to a very large extent, and the hornblende becomes quite secondary in quantity. The plagioclase, hornblende, and pyroxene show as a rule, good crystal form, though the plagioclase is often obscured by small inclusions or by alteration. As accessory minerals, magnetite and titanite are abundant in all sections, and quartz in only a few. Secondary minerals are chlorite, epidote, and calcite, the first being very abundant in the augite bearing varieties. The texture in both kersantites and camptonites might be either porphyritic or panidiomorphic.

The plagioclase crystals are medium basic, and show no zonal structure as in the plutonic rocks. Albite twinning is not very common, or else it is obscured by the formation of secondary minerals. Twinning after the Carlsbad law, however, is very common. The hornblende of the kersantites is dark to light green, and not strongly pleochroic. It is usually quite fresh, but sometimes goes over to epidote or shows a tendency to alter to chlorite. The pyroxene has the typical augite habit, forming tabular crystals of very pale green colour, similar to the plutonic variety found in the gabbro. It is very resistant to weathering, and rarely goes to hornblende, though more often to chlorite. In the typical camptonites, chlorite is very abundant, and, with some calcite that occurs with it, is the result of alteration. It appears as a pale green mineral, generally isotropic in character, and of low index of refraction. It less often has a weak double refraction, and is then seen to be made up of a felted mass of intergrown fibres. The intimate intergrowth of these fibres probably accounts for its anomalous isotropism. Calcite is also associated with the chlorite as a secondary mineral. Titanite is very abundant, more so in the camptonites than the kersantites, and is always associated with the pyroxene in small wedge-shaped faintly pleochroic crystals.

In age, the lamprophyres follow, apparently at a short interval, the intrusion of the stocks of diorite and gabbro, but they are not found intrusive into the granodiorite.

Keratophyre.—Certain rare dike rocks, always referred to in the field by the name of quartz porphyries, are better designated by the more restricted name keratophyre, a rock intermediate between the porphyries and porphyrites. These rocks also have affinities to the trachytes, but are quartz-bearing. In the hand specimen, the rock is dark, fine-grained, and dense, and of a slightly porphyritic structure, showing phenocrysts of glassy quartz and twinned feldspar embedded in a dark and almost glassy ground-mass. The best known locality where this rock occurs is in the Nickel Plate mine, where it is found as a dike 4 to 6 feet wide, lying to the south and west of the main ore body, and forming its boundaries on these sides. It has no uniformity of strike, but in the above locality it seems to curve about so as to form the arc of a quadrant.

Under the microscope, the rock is seen to be made up almost entirely of feldspar, both as phenocrysts and in the ground-mass. Its structure is porphyritic, and the prevailing phenocryst is an acid plagioclase, which cannot be determined more specifically. Large, clear, glassy phenocrysts of quartz are also present, but are much less abundant than the feldspar, and these invariably show rounded and corroded outlines with embayments of the ground-mass in them. The texture of the ground-mass is very fine, though crystalline, the individuals being very irregular in outline and intergrown with each other. The constituents of the ground-mass are largely feldspars, all untwinned, and of an apparently alkaline variety. Some quartz is also present in the ground-mass, and a ferro-magnesian mineral which is probably hornblende. Accessories, in the form of sulphides, are sparingly present, but on account of the proximity to the ore bodies may be of secondary origin.

The age of the rock is determinable only within wide limits. It is known to cut the Palæozoic sediments, and the intrusive sheets and apophyses from the diorite and gabbro stocks. On the other hand, it is cut by the andesite dikes which are the youngest rocks in the district. Its relation to the granodiorite batholith is unknown. From its general character and appearance it is probably older than the granodiorite, and until further evidence is obtained is tentatively referred to the period following the irruption of the stocks of diorite and gabbro.

Aplite and Rhyolite.—The aplites are dikes or apophyses genetically connected with the granodiorite batholith, and having a porphyritic structure, with phenocrysts of quartz and feldspar embedded in a fine-grained acid matrix. With these are associated some rhyolite dikes, for both are thought to be modifications of the same granodiorite magma, and referred to the same general geological age.

The aplites are easily recognized by their light pinkish colour, and their frequently speckled or porphyritic appearance. They have not any marked uniformity of strike or size, and are generally found at no great distance from the edge of the granodiorite batholith. To the east of the stamp mill several of these intrusions can be traced directly from the granodiorite, running off as tongues into the overlying sediments. In these cases they are not of great length, and quickly diminish in size and pinch out. Others of the same character are noted in connexion with the dike like mass of granodiorite crossing the gravity tram-line above Central station.

Pinkish rhyolite dikes, showing no crystalline texture to the unaided eye, are found on the Stemwinder hill, and on the Kingston mineral claim. These have a general north and south trend, and are more persistent in distance than the aplites. They cut all the rocks of this district, sedimentary and igneous, except the andesite dikes.

The aplite is a reddish or pinkish rock, having a speckled appearance, which cannot be confused with any other rock in the district. It contains crystals of quartz and feldspar, and sometimes mica embedded in a fine-grained ground-mass that is almost or quite aphanitic. Under the microscope the dominant phenocrysts are found to be feldspar, both orthoclase and plagioclase, with quartz, the latter showing the characteristic corroded outlines. Much less abundant are crystals of mica in large individuals. Mica, however, is absent in many of the aplites, and the only phenocrysts are these quartz and feldspar. The ground-mass is generally a minutely crystalline aggregate of quartz and untwinned feldspar, which is, however, quite distinct in character from the ground-mass of the dikes of rhyolite.

In the rhyolite dikes, while the texture is somewhat similar to the aplites, the phenocrysts are much less abundant. Like the aplites, however, the phenocrysts are quartz, orthoclase, and plagioclase. These are embedded in a very fine-grained acid ground-mass, the components of which cannot be accurately determined. There is a pronounced fluxion structure to the rock mass, which is accentuated by the presence of a dark opaque substance, which is arranged in rudely parallel lines. The ground-mass also shows frequently large shadowy crystals, which under crossed nicols give a patchy wavy extinction. These are thought to be the result of a devitrification of a glassy ground-mass, and this, in conjunction with the fluxion structure, seems enough to justify the classification of the rock as a rhyolite.

The aplites and rhyolites are closely connected with the intrusion of the granodiorite, and in the case of the aplites are seen to be simply apophyses originating in the granodiorite and penetrating the older rocks as dikes which do not persist very far. They are, therefore, contemporaneous with the granodiorite.

Andesites.—The andesites are light to dark green rocks, generally of very fine grain, or only slightly porphyritic, occurring in dikes up to 8 feet in width. They are very soft rocks, and where exposed are noted as occupying depressions rather than forming ridges. They are much more persistent than any of the other dikes, and are also more uniform in strike. This strike varies only from about N. 10° W. to N. 5° E. and is not noticeably conformable with any of the great fault planes.

These dikes are not abundant, but are found both in the Sunnyside and Nickel Plate mines, cutting the ore bodies, and were noted also at Bradshaw cañon, and to the east of the Daly Reduction Company's stamp mill. They cut all the rocks of the district, both igneous and sedimentary, without any exception.

In the hand specimens, these rocks are light to dark green in colour. They occasionally show a porphyritic structure, but more often consist of small fine needles of black hornblende and glistening laths of feldspar, closely compacted together, and with a tendency to parallel arrangement. The ground-mass is aphanitic, and quite indeterminate.

Under the microscope, they are seen to consist essentially of two constituents—feldspar and hornblende. These two constituents occasionally occur as phenocrysts in a ground-mass of the same components. The feldspars are long and lath-shaped, and are plagioclase of the variety andesine or oligoclase. They show only a little variation in size, and the larger ones are only 0·3 of a millimetre in length. The hornblendes are not so abundant as the feldspars, and when they occur in phenocrysts are generally much altered. These two constituents are, as a rule, arranged with their long axes roughly parallel to each other, and have a marked trachytic structure. Augite is sometimes abundant in small grains, but there is never any biotite. Titanite is an abundant accessory constituent, and there is often much magnetite.

The ground-mass is holocrystalline, but occasionally shows some glassy residue. It is composed of small feldspar laths and small green hornblendes. The feldspars show some decomposition. Augite is rare, and when present quite unaltered. The hornblende shows a great deal of alteration to chlorite, particularly in the phenocrysts. Calcite and epidote are also common as secondary products.

In age, the andesites are the youngest consolidated rocks in the district. They are known to cut the Palæozoic sedimentary rocks, as well as the diorite and gabbro stocks and the granodiorite. They are, therefore, at least Tertiary in age, and may be connected with the extrusive lava flows of middle or later Tertiary age, which have such a wide distribution in neighbouring portions of the Similkameen district.

SURFACE DEPOSITS.

The only rocks in the Hedley map younger than the sedimentary rocks of the Cache Creek group, and the igneous rocks already described, are the unconsolidated glacial and stream deposits. These are not of any economic importance, and consequently have not been closely studied. The stream deposits only are of sufficient importance and extent to be mapped and outlined by a separate colour on the geological sheet.

Glacial Deposits.—The former existence of a Cordilleran ice sheet, covering the whole of the Similkameen district, preceded and followed by valley glaciers, has frequently been referred to. Evidence of the presence of this glacial ice is preserved to us in the broad U-shaped valley of the Similkameen river, and also in the deposits left behind on the plateau on the retreat of the ice. These deposits are of limited extent, and not well defined, so that it would be impossible, or very difficult to map them. They consist of glacial debris, quite unassorted, and lying as a thin mantle over a great part of the map. Large granite boulders brought down by the ice from the granite areas to the north are scattered over the whole area, and up to the highest point in it.

Stream Deposits.—The stream deposits are easily distinguished from the other drift deposits, though occasionally at the base of

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Exposed section of stream deposits on Twentymile creek

the steeper slopes they merge with, or are covered by the talus from the cliffs. In the Similkameen valley they form a broad band about 3,000 feet across, and of unknown but probably great depth. It has been roughly estimated, by projecting the slope of the valley [illegible] beneath the stream deposits, that the thickness of these in the middle of the valley must be at least 300 feet. This gives a total amount of alluvial deposits quite out of proportion to the present size of the stream. This fact indicates a former period of rapid deposition, in a valley deeper than the present one, by a stream overloaded with debris, and greater than the present one. This period belongs to a time immediately following the retreat of the glaciers, when the stream was laden with glacial debris. At a later stage in its history, the stream began to cut down into the gravels previously deposited by itself, and numerous benches were found, which mark successive stages in this process. On the west side of the mouth of Twentymile creek almost a dozen such benches can be counted, each rising only a few feet higher than the lower one. The highest of these benches at Hedley stands at an elevation of about 1,700 feet above sea-level, while the present level of the water in the river is about 1,560 feet, or 140 feet below.

These benches are made up of well rounded boulders of large size, lying under about 6 inches of light coloured sandy soil. Associated with these gravels are beds of almost white fine-grained silt, which probably represent stationary conditions for a short time, or deposition in the quiet waters of a lake. On the banks of Twentymile creek, to the northeast of the town, a section of these stream deposits, 40 feet in thickness, is exposed in a cliff. (See Plate XIII.) The upper beds of this cliff, which is just below the 1,700 ft. contour line, are made up of angular as well as rounded boulders, showing some evidence of stratification. These are interstratified with beds of finer material, almost sand, and quite distinct from the beds of coarser material. Below this are about 16 inches of very fine white silt, which has an elevation of 1,680 feet above sea-level. Underneath this silt bed are beds of sand and gravel, similar to those above. More extensive deposits of white silt were noted in the upper portion of Twentymile creek, but outside the map. These were at an elevation approximately measured by aneroid of 3,000 feet above sea-level. This is somewhat higher than similar deposits of this kind mentioned by Dawson, but they are probably of a like origin, namely, deposition in the quiet waters of a lake during or after the final retreat of the glacier from this region.

STRUCTURAL GEOLOGY.

The different kinds of structure shown in the rocks of the region include faults, folds, fissures, and joints. The most important of these are folds and faults. The actual folds seen are of small dimensions, but it is believed that the whole series of sedimentary rocks represented in the map is merely the western limb of a great anticline, whose eastern limb is to be found on the eastern side of Eighteenmile creek, and whose crest has been largely eroded away or truncated by igneous intrusions. The general strike of all these folds is in a northerly direction. Faults are not as numerous as might be expected from the number of igneous intrusions, and only a few of these have been recognized in the field, and mapped. Undoubtedly many more occur, which have not been detected. No uniformity of direction has been recognized in the strike of these faults, though the main faults of the region, on which the direction of Twentymile creek to some extent depends, have a strike of N 30° E and of N 30° W.

FOLDS.

There is a general uniformity of dip to the west of all the sedimentary rocks in the region. This, as before stated, is a fact which is associated with the idea that all the rocks merely represent one limb of a great anticline. Starting at the western edge of the sheet, the dips are very high, and often vertical, and going eastward across it, these dips gradually flatten out, until on the eastern slope of the Nickel Plate mountain they are only about 15° to the west. Farther eastward they appear to dip in the other direction altogether. The original crest of this anticline was probably over the bed of Eighteenmile creek, and the general trend of its axis about north and south. This is the general trend of the Okanagan range of mountains, though there is no genetic connexion between the two. This anticlinal fold was produced during the first known deformation of the region, and long before the Pliocene uplift which produced the Okanagan mountains. The compressive forces, however, to which the uplift was due in both cases, were exerted in a general east and west direction, in conformity with the other great movements of the Cordilleran region.

Apart from this major fold, there are many folds [illegible] order, all of which are not so clearly of the origin [illegible] fold. These are best exhibited in the siliceous and ar[illegible] portions of the series, and are seen in Redtop gulch, in [illegible] cañon, and on the face of Striped mountain. All of these [illegible] closely compressed, and some are faulted along the axis [illegible] cline. The massive limestone members associated with [illegible] ceous and argillaceous beds have not, for some reason, been [illegible] by these forces, and they preserve their uniformity of dip [illegible] of them. The axes of these minor folds conform in a general w[illegible] with the axis of the main anticline.

Compressive stresses at right angles to these have produced a second group of minor folds consisting of low anticlines and synclines, with east and west axes, and in these the massive limestone beds are involved, as well as the adjoining siliceous and argillaceous beds. Compression in this direction has been very much weaker than in the north and south direction, and the resulting low folds are well exhibited in the neighbourhood of the Sunnyside mine, and on the face of Stemwinder hill.

FAULTS.

Character and Distribution.—The second result of deformation in this region is the series of faults that cut across the formations. As might be expected, the largest proportion of these are so small that they are not worth while mapping. Faults were noted which have a throw of 1 inch only, while the great Bradshaw fault has a throw of at least 800 feet. Many others intermediate between these two extremes are to be seen in different parts of the region.

As a rule, the plane of the fault is a clean cut break attended by little local disturbance of the adjoining strata, and this is characteristic of the faults of smaller magnitude. In a few cases there is to be seen a slight bending of the adjoining beds, due to friction, and a dragging down of the displaced masses. This is shown in the fault lying under the trestle at the head of the Horsefly gulch, where the ends of the strata on the upthrow side are bent down by the dragging force of the strata on the other side of the fault line.

Other common accompaniments of faulting are the breccias, which are the result of the friction of one side against the other.

A breccia of this character is seen in a narrow fault plane running diagonally down the face of Stemwinder hill in a direction about N 80° E. The fault plane has in this case been later occupied by a dike. In the Bradshaw fault the plane of the fault lies in the bottom of the cañon, and is masked by the drift and talus in the cañon bed. No friction breccia was apparent, but in a thin section of the mica diorite dike lying to the west of the cañon a crushed and brecciated appearance is exhibited in the minerals making up the section. If this microscopic brecciation is due to faulting—and it is a plausible cause—then we know the relative age of the faulting. A feature allied to this friction brecciation is seen in the northern end of the Nickel Plate mine workings. There is a zone of fracturing here running N 70° W which is marked on the surface by a depression, and while there may not be any actual displacement of adjoining strata, there has been rather strong fracturing tending toward faulting. The Nickel Plate ore body adjoins this fault zone on the west, and whereas the fault zone has not been mineralized by the solutions which produced the ore bodies, we have in this case, also, a clue to the relative age of the faulting. The most apparent, and at the same time the greatest fault in the whole district, is that which has already been referred to as the Bradshaw fault. The plane of this has a direction of N 30° E, and it follows the main branch of the Bradshaw cañon from Twentymile creek in almost a straight line to the top of Aberdeen ridge. (See Plate XIV.) Its course in the upper portion is marked by a cañon covered with a light yellow talus. The dip of this fault plane is very high, and the downthrow is on the west. It was found very difficult to calculate the amount of displacement in this fault, because the conditions were complicated by the presence of two other faults on the east side, apparently tributary, and running into the main fault. In contrast to the Bradshaw fault, the upthrow side of each of these two is on the west, and the displacement is measured in hundreds of feet. Each fault is marked by a narrow box cañon, in the lower one of which is a small water-fall.

The result of all this faulting in the Bradshaw cañon has been to thrust up a large triangular block of the Nickel Plate formation between the two outer fault planes, so that the top of the Sunnyside limestone has been brought, at the waterfall, directly against the lower beds of the Red Mountain formation, and on the other side against the upper Red Mountain beds. The total result, as repre-

The Bradshaw fault-line in Twentymile creek and Bradshaw cañon.

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sented in the cañon below the point where the tributary fault runs into the main one, has been to bring the Sunnyside limestone, itself directly against the lower volcanic beds of the Red Mountain formation, giving a total displacement of about 800 feet.

A fault of considerably less magnitude, but one easily recognized is that running down the deep and narrow Climax cañon. The direction of this is about northwest, and is probably a continuation of the line of weakness represented by the fault at the head of the Horsefly gulch. This fault plane is also steeply inclined, having its downthrow side to the south. Where exposed by prospecting operations, it is seen to be a clean cut break without any accompanying friction breccia.

Almost parallel to the fault plane of the Climax cañon is the strike of the granodiorite dike which runs diagonally across the mountain from Eighteenmile creek almost to Twentymile. If this line were produced to the northwest it would be found to fall into the bed of Twentymile creek above the first bend. These facts are significant, and while no vertical or horizontal displacement is apparent along this line to show that there has been faulting, the fact that two such structural features as a large dike and a deep cañon lie in the same line, indicates that there is here at least, a line of weakness which determined the presence of both these features. Also, the fact that faulting has taken place along a plane parallel to this line suggests the possibility of there having been faulting here.

An excellent example of repeated normal faulting is furnished by the exposure of volcanic rocks to the south of Central station. There are three distinct faults, each marked by a short dip in the contour of the surface, and each with downthrow to the south of from 20 to 50 feet. The result of this is a repetition of strata as one walks across the strike of the faults in a southerly direction.

Topographical Expression.—All of the apparent and easily studied faults of the region have very high or vertical dips, consequently it is difficult to determine from surface exposure the nature of the dislocation, that is to say, whether the upthrow side has been thrust upward while the downthrow remained stationary, or whether there has been a simple splitting, with a sinking of the downthrow side, while the upthrow remained stationary. The primitive topographic expression of faults of this nature, before subdued by erosion, would be a simple cliff, but it is obvious that such expression could only be found in very recent faults or in regions where erosive action is weak. Erosion would tend to destroy this feature as time went on, first by a filling in with talus from the cliff, and later by a smoothing down of the cliff itself. Evidence of such primitive forms is still preserved in the case of several of the faults, though very much subdued by the forces of erosion. They now exhibit various degrees of erosion, but it would not be safe to attempt to estimate the age of these faults from the maturity of their erosional form, for the rocks through which they cut are of varying degrees of hardness. The Bradshaw fault still preserves to a limited degree the original topographic form, but this is now very much subdued. In the case of the Climax fault, and the Stemwinder fault, the primitive cliff-like form is still to a great extent preserved, and if all things were equal, we should say that these two were very much more recent than the other. As a matter of fact, each of the two latter faults lie in rocks which are much more resistant to weathering than the other.

Another topographic expression, and one which appears to be connected with most of the faults in the region, is the formation of deep sharp cañons or gentle sags in the surface of the ground. The former is illustrated in the case of the Bradshaw and Climax faults, and the latter in the case of certain faults lying to the north of the Nickel Plate mine. This feature has, to a very large extent, governed the whole system of drainage throughout the district, and in many cases the water courses now follow the fault planes. Twentymile creek has been already mentioned as following in its lower part the strike of the Bradshaw fault, and it is very probable that the course of the stream was influenced by reason of the line of weakness along which the faults had taken place.

Age and Cause of Faulting.—The lack of any sedimentary strata younger than the oldest rock is a great drawback in fixing definitely any event in the subsequent geological history of the region. So it is with regard to the age of these faults. Some of the faults seen on the southern face of the mountain overlooking the river can without doubt be referred to the time when these rocks were folded, for they are simply the result of close folding pushed beyond the breaking point of the strata. These are undoubtedly the oldest faults in the region. The most apparent faults, and those which still retain, though in a mature state, the original topographic form, are of a more recent date. These cut all the rocks in the region, except the granodiorite, and the relation of many of them to the granodiorite could not always be determined, on account of an absence of faulting in that vicinity. The opinion was formed from a study of all the conditions that the majority of the faults are quite recent in age, some being formed previous to the granodiorite intrusion, or accompanying it, and some probably later.

Reasons for this are that the faults still preserve, to a certain extent, their primitive topographic form. That some of them are earlier in age than the intrusion of the granodiorite is proved by the fact that a dike of this rock occupies one of the principal fault planes, namely that running N 50° W. At the same time a fault with a strike of N 80° E is filled by an aplite dike which is thought to be genetically connected with the granodiorite intrusion. That some of the faults are later than the granodiorite intrusion is suggested by the fact that their fault zones show no evidence of cementation or silicification of the friction breccia, a phenomena which might be expected to accompany the intrusion of such a large batholithic mass as the granodiorite. It is certain that most of the great faults in the region are later than the formation of the ore bodies, and this fact must constantly be borne in mind by the miner, for it may have an important bearing on the problem of working the ore bodies.

With regard to the cause of faulting, doubtless many of the earlier faults could be referred to causes accompanying the intrusion of the different igneous masses, but for those later than the igneous rocks, some other force is necessary. The latest recorded orogenic movement that might have produced these faults was the Cascade uplift of Pliocene date. The nature of this uplift was such that vertical faults, like those recorded in the Hedley sheet, might readily be produced by such a simple warping, without lateral compression.

FISSURES.

Fissures are of little importance in the economic geology of the region, and though fairly abundant, are generally of small size, and workable ore bodies have yet to be discovered in them. They are probably due to the same causes that produced the faults, but operating with different degrees of intensity. This does not imply that they were produced at the same time, though many of these fissures have the same strike as some of the faults. The most pronounced fissuring is about N 30° E. or parallel to the great Bradshaw fault. Examples of this are seen in both the Nickel Plate and Sunnyside mine. These show little or no evidence of mineralization by the metals, and are, therefore, presumably much later than the formation of the ore bodies. Another strong line of fissuring is about northwest, and an example of this is seen in the Nickel Plate mine behind the bunk house. This is a well marked and strong fissure, filled merely with soft clay, and carrying a slight gold value in certain places. The fissuring is evidently quite recent, and much later than the formation of the ore bodies, the small gold value in the vein being accounted for by a leaching of the strata through which the fissure runs. Another fairly pronounced fissuring has a strike of N 60° E.

JOINTS.

Jointing is best exhibited in the massive granodiorite in the bottom of the Similkameen valley, but the direction of the joint planes was not found to conform to the three well marked lines of fissuring. The forces which produced these two features appear to have been quite distinct, and independent of each other. Four well marked planes of jointing were noted and the bearings of these were N 50° E, N 80° E, S 65° E, and south. The two stronger directions were N 50° E and N 80° E. A discussion of the cause of this jointing would be of a purely theoretical nature, and sufficient data were not obtained for this purpose.

GEOLOGIC HISTORY.

Introductory Statement.—The earliest events in the geological history of the Hedley area are not now recorded in the rocks that are exposed on the surface, and it is doubtful if records of these events will ever be discovered. Batholithic irruptions of igneous rocks have been instrumental in obliterating much, and it is probable that they may have totally destroyed all of the earlier records even outside the sheet.

The old land, from the erosion of which the Cache Creek sediments were derived, probably lay to the east of here, rather than to the west. The nearest area of supposed Archæan rocks is to be found on the eastern shore of Okanagan lake, about 20 miles to the east, but the intervening country is virtually unknown, geologically. It is presumed, however, that this Archæan area was a land mass from the earliest times, and continued so through all the geologic history of southern British Columbia, forming an axis on either side of which later sediments were laid down.

Evidence obtained from the pyroclastic rocks interstratified with the sediments shows that these rocks were derived from a volcanic source, east or northeast of the sheet, and at no very great distance. The characters of these pyroclastic rocks also indicate active volcanic vents standing above the level of the water, either as islands or on the edge of the old continent, and discharging their ash and other materials into the neighbouring seas, which were also depositing their normal load of quartzites, argillites, or limestone. In this we have corroboration for the idea that the Cache Creek sediments originated from the erosion of land to the east.

An indefinitely long period of time is necessary for the deposition of all these sediments, and as in the case of the beginning, the end of this period is not recorded inside the sheet itself, and may be destroyed outside the sheet by later igneous intrusions. Finally, when this period was definitely closed, and the uplift followed, there is no evidence to show that there was ever again a sinking of this part low enough to allow the sea to encroach for the formation of other sediments. Consequently, from that period almost up to the present, there is virtually nothing by which to fix definitely any events in the history of the region. Within this time there were intrusions of different kinds of igneous rocks, followed or accompanied by tilting, faulting, and other deformation of strata.

After these things were accomplished, we know that there was regional uplift and glaciation accompanied by a great deal of erosion at all times. The later stages of all this are now recorded in the present forms of the land surface, and in the superficial deposits of the valleys, etc.

The geological history thus outlined may be divided for convenience, into three periods: (1) Cache Creek sedimentation; (2) Intrusion and deformation; and (3) Glaciation and development of the present topography.

Cache Creek Sedimentation.—The general conditions under which the Cache Creek sediments were laid down can be inferred from a study of the characters of these sediments. The main facts that throw light on these conditions are: (1) the conformable sequence through great thickness of strata; (2) the fineness of materials in these strata; (3) the sudden changes from one kind of sediment to another; and (4) the presence of volcanic materials throughout. These facts indicate that there were no great orogenic movements sufficient to produce any unconformity in sedimentation, though the frequent sudden changes from limestone to quartzite might indicate minor oscillations of level; but not sufficient to raise this surface completely or much above sea-level. Again, the fineness of materials indicates either a considerable distance from shore, or more probably a low relief to the land from which the sediments were derived, so that erosion was very gentle. Also, the presence of volcanic materials indicates frequent and sometimes long continued periods of explosive volcanic activity, with simultaneous deposition of the volcanic materials with the true sediments. The absence of any evident unconformity through many thousands of feet of sediments, demands for their formation a sinking sea bottom which, however, did not maintain an even uniform pace, but one in which there were numerous pauses and even rises of level. An instance is on record where one of these rises was sufficiently high to form a fine-grained conglomerate, and though this might indicate a discontinuity of sedimentation for a time, no unconformity is apparent.

The different formations represented on the map have each some peculiarity, under which deposition took place.

Redtop Epoch.—The lowest portion of this formation was accumulated in clear water, where the Stevenson limestone was deposited. This represents a long period of stable and quiescent conditions. Following this, in the middle portion of the formation, there was, on the whole, a change to shallower water conditions, with only occasionally reversions to clear water conditions of limestone deposition. Accompanying this, a period of explosive volcanic activity was ushered in, which continued intermittently throughout the deposition of all the sediments represented in the area. Toward the close of the epoch, there was a slow sinking of the sea floor, during which there were many halts or changes in sedimentation, and throughout all, frequent outbursts from active volcanoes, the ash and fragments from which were blown out and fell in the sea, where they became interstratified with the true sediments.

Nickel Plate Epoch.—This period is virtually a repition of events as they happened in the preceding epoch, with almost a total elimination of volcanic activity in some sections. The length of time however, during which clear water conditions prevailed, was relatively longer, and consequently a greater quantity and thicker beds of limestone were deposited. The base of this formation, namely the Sunnyside limestone, is the most massive and thickest limestone member in the whole Cache Creek group here represented, indicating a very long period of stable clear water conditions. The middle of the formation shows again frequent changes in the sediments, denoting in this case, changes in sedimentation, and not intermittent volcanic outbursts. These changes were not so sudden as the outcrops would suggest by the sharpness of the bounding line between the different beds, but the microscope shows rather a transition by a mingling of constituents near the contact.

Before the close of the Nickel Plate epoch, volcanic explosions of great importance, but localized, took place, and a series of volcanic tuffs and breccias were deposited in the upper part of the formation, directly below the Kingston limestone member. The closing stage of this epoch was one of quiet sedimentation when the sea had again advanced to a higher level.

Red Mountain Epoch.—This was a relatively short period of time, but one of catastrophic events. The lower part of the formation—that intercalated with the Nickel Plate formation—has already been mentioned. At the close of the period represented by the Kingston limestone, there appears to have been a very sudden rise of level, which is recorded in the conglomerate streaks that are found in the upper part of this limestone; and simultaneously with this rise was the beginning of the greatest and longest period of vulcanism that is recorded in the history of the whole area. This rise was not a regional uplift of the whole sea floor, but rather a local uplift of a small portion of the country to the northeast, where it is supposed the volcanic vents were situated from which the tuffs and breccias were derived. This may have tilted the northeast portion of the area, so that it became a land surface, while the western portion certainly yet remained submerged, and the normal processes of sedimentation here continued. In harmony with this hypothesis is the fact of the appearance of the conglomerate streaks in the limestone in the northeast portion of the area, and the evident thickening of the volcanic beds in the same direction. This period was not closed by any sudden cessation of volcanic activity; but, by a gradual diminution in intensity, and a lengthening of the time between successive outbursts, it passed gradually into the Aberdeen epoch.

Aberdeen Epoch. This is characterized throughout by rapid and sudden changes in deposition, represented by the alternation of different kinds of rock. Some of the changes might indicate either oscillations of level, or simple changes of sedimentation, but at the same time, a great many of them record intermittent explosive outbursts of volcanic activity. The rocks show that there were never any very long periods of stable conditions, when one particular kind of sediment might have been deposited, but there were frequent changes; and many of the changes of sedimentation were accompanied by volcanic action.

INTRUSION AND DEFORMATION.

The close of the deposition of the Cache Creek group was probably brought about by an uplift of the whole region, for no younger sedimentary rocks are now found above these; and from that time on to the present, the region shows no evidence of having been submerged, and has probably been subject to continued and uninterrupted erosion.

Igneous intrusions of various kinds of rocks, with numerous dikes, followed the uplift. The exact time in geological history when the igneous intrusions took place is not known, and all we can say is that they are post-Carboniferous and pre-Quaternary. The sequence, however, in which the different intrusions followed each other has been worked out in all cases, except in that of some of the younger dike intrusives.

The oldest of these igneous rocks are the diorite and gabbro rocks, which were previously shown to have been irrupted at two different periods closely following each other. The nature of the crystallization of these rocks indicates that the surface now exposed must have been at considerable depth when cooling was effected, and they have since undergone deep erosion. The irruption of the quartz diorite was slow and gradual, showing no evidence of cataclastic movement, or of form in having thrust aside the intruded rocks. In fact, the process was so quiet that detached portions of the sedimentary rocks in the igneous still preserve their strike and dip, in conformity with the rest of the beds that have not been intruded by these rocks. The gabbro intrusion, however, was not so gentle in its action, for it has frequently formed a brecciated contact with the intruded sediments.

It has been very difficult to determine whether the tilting and deformation of the strata which is now seen in the sedimentary rocks happened before the intrusion of the diorite-gabbro complex, or whether it was later. The evidence at times might point to a time of tilting later than the diorite-gabbro intrusion, because, in a great many instances, the sheets of porphyry which emanated from the main masses and penetrated along the bedding planes of the sediments, have been included in the folding. This, however, might also have happened after the tilting, and the sheets may have simply followed the bedding planes of the strata as the lines of least resistance. Most probably the deformation of the strata and intrusion of the diorite are genetically connected with each other. In relation to the granodiorite, there is no doubt that the strata were tilted to their present attitude before the erosion of this rock, so that we have a limit, at least in this direction, to the time in which the tilting might have occurred.

The formation of the primary ore deposits is attributed to the period following the intrusion of the gabbro, and as a last result of this intrusion also, a great many lamprophyre dikes were formed.

The next great event in the geological history of the district is the irruption of the granodiorite, in the form of a great batholith. This appears to have acted very quietly, and without materially disturbing the intruded rocks. It was accompanied by some contact metamorphism, but by apparently little mineralization. Aplite and quartz porphyry dikes are also connected with this irruption.

The last event recorded by the formation of rocks is the intrusion of some rhyolite and andesite dikes which cut the granodiorite. This event concludes the igneous history, and though there is nothing to mark the time at this point, it is probable that it would bring us well into Tertiary times at a time when great surface flows of a basaltic nature were taking place in certain portions of the adjoining country.

Deformation of the rocks by faulting has occurred at different periods, but no definite statement can be made that faults with a certain strike belong to a fixed period of time. It is certain that the greatest and most apparent faults are later than the intrusion of the quartz diorite. None are known to occur in the neighbourhood of granodiorite, and so the relation to this rock is unknown.

Either these faults have accompanied the intrusion of the granodiorite batholith, or else they are connected with the orogenic movements involved in the Cascade uplift. The nature of the faults is such that they may be referred to either period of time. It is certain, however, that they were of such recent date that, to a limited extent, the topographic expression of these faults is still preserved.

GLACIATION AND DEVELOPMENT OF PRESENT TOPOGRAPHY.

The general uniformity of level of the higher points of the Interior Plateau region is a well known fact, and the area under discussion is a part of that plateau region.. The development of the present topography of the upper levels of the region is supposed by Dawson to be due to erosion taking place throughout Eocene times, following an uplift at the close of the Cretaceous.[1] Chiefly because no deposits referable to the Eocene have been found in this part of the Cordillera it is assumed that this was a time of denudation. At the same time a stability of elevation prevailed long enough throughout this period of denudation to establish conditions of well marked peneplanation over the plateau. This erosion period determined the summit levels of the plateau and developed on them the rounded outline of a mature topography. Dawson concludes that the base-level which obtained at the close of the Eocene period stood 2,000 or 3,000 feet lower in relation to the sea than it does now. In the Hedley area the 4,000 ft. contour line approximately marks a distinct change in topography, and it is possible that this line represents the old Eocene base-level in that region. Traces of the old erosion period are still to be found in the broadly flaring valleys of the creeks, above the 4,000 ft. contour line; while below this is a totally different kind of topography referable to a different and later period of erosion, and it is not likely that the old Eocene erosion cycle could ever have acted below this line.

Minor local disturbances of elevation and depression occurring throughout the Oligocene and Miocene periods in other portions of the Cordillera are not recorded in the Hedley area.

[1] G. M. Dawson, Bull. G. S. A., Vol. 12, 1901, p. 89.

The Cascade uplift of Pliocene times appears to have been effective in this region in raising the whole of the land surface, and reviving the streams, and thus instituting a new cycle of erosion. This revival of drainage is responsible to a very large extent for the youthful appearance of the topography below the 4,000 ft. contour, but it has been somewhat masked in the main valley below by later glaciation.

What determined the position of the streams in the first place is not known, and can only be conjectured. In the case of the Similkameen valley no data are at hand, and we infer from the way in which it cuts across the Okanagan range of mountains that it must have occupied its present bed prior to Pliocene times, when the uplift took place, and it is, therefore, an antecedent stream.

In the case of Eighteenmile creek, there is an apparent relation between the course of the stream, and the strike of the sedimentary rocks through which it cuts.

The intimate relation of certain stream courses to faults, has already been pointed out. The most striking instance of this is the case of Twentymile creek, which follows the course of the great Bradshaw fault for a couple of miles before entering the Similkameen river. Examples of this are also seen in some of the tributaries of Twentymile creek, which follow fault lines that are not in conformity with the trend of the Bradshaw fault.

The tributary streams of the Similkameen river are still very active in erosion, and have much to do to develop a thoroughly graded course from headwaters to the Similkameen valley. These are tending to destroy all evidence of glaciation in their own valleys, while the Similkameen valley itself still preserves the characteristic shape induced by this glaciation.

One of the last geological events recorded in the history of this region is that of glaciation. This has left many records of its presence in the present topography. On the upper levels its action has not been so marked as in the Similkameen valley, and as before stated, this is accounted for by the supposition that glacial ice covered the upper levels for a relatively shorter period of time than the valleys, while the depth of ice was also thinner, and so erosion
...aker. In these upper levels the principal record of the
...ering of glacial drift, and the presence
...iation has had a much greater

influence on the topographic form. The broadening of the valley bottom, rounding of projecting shoulders, and to some extent, the formation of hanging valleys are all expressions in the topography of glaciation.

The great Cordilleran glacier at its height covered all the summits in the Hedley quadrangle, as well as the adjoining country during the glacial period. Some of the higher points in the Okanagan range which were ascended, showed the ice cap to have covered them, but none were much more than 7,000 feet above sea-level; so that while we know that the upper limit of the ice was above this level, no data could be obtained in this region to show how far above. Evidence obtained by Dr. Daly in adjacent regions fixes the upper limit of the ice cap at about 7,500 feet, and this coincides with the results of investigations on the south side of the boundary line.[1] It has been established by these observers that the Quaternary ice in the extreme northern part of Washington, directly south of here, and on the Canadian side, existed as a general ice sheet covering almost the whole surface. Farther south, however, the ice sheet was not general, but it occurred rather as valley glaciers or tongues pushed southward along these valleys from the main ice sheet[2] to the north.

In consequence of the Hedley district being within so short a distance of the southern limit of the general Cordilleran ice sheet, we should expect the results of this glaciation of the higher levels to show that the ice was losing its great power of erosion, and was rather depositing its load of debris. This is exactly what we do find. Grooved and striated rock exposures are very rare, and roches moutonnées are almost unknown; while on the other hand the covering of rock detritus is very widespread and heightens the effect of mature relief which the topography already had.

In the lower levels, however, erosive action has been much more pronounced. The evidence of this appears in the characteristic forms produced by the glaciers in the erosion of the valleys. The Similkameen valley is a typical glacial valley (see Plate XV). The erosion of the valleys in contrast to the surface of the plateau, can be better appreciated when we reckon the thickness of ice overlying each of these places. As before stated, the maximum thickness over

[1] Smith, G. O., and Calkins. U. S. G. S. Bull. 325, 1904.
[2] Bailey, Willis. U. S. G. S. Bull. 40, 1887.

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Effect of glaciation on the shape of the Similkameen valley.

the Similkameen valley at Hedley was about 6,000 feet, while at the same stage it was only from 1,000 to 1,500 feet deep on the upland.

It is impossible to say for how long a period glacial conditions were at their maximum, and covered the whole region, including the Okanagan range, but it is more than likely that for a very considerable period the ice existed here only as valley glaciers, moving slowly down the present grade of the Similkameen valley through the Okanagan range. This valley glacier[1] Russell has called the Similkameen glacier. Its source was in the Cascade mountains at the heads of the Similkameen and Tulameen rivers and it flowed down through the Princeton basin and eastward along the Similkameen valley to join the great Okanagan glacier. Much of the territory in and about the Princeton basin is considerably below the elevation of the gaps in the Okanagan range, and here the Similkameen glacier must have spread out over a wide area. As the glacier progressed eastward, however, the surface of the upland gradually rose, so that all the ice would be confined between the sides of the Similkameen valley, and as a result the speed would be accelerated, and the erosive action greatly increased. This in a great measure would account for the extreme glacial action in the main valley, in contrast to the weaker action on the uplands.

Evidence in support of the idea of valley glaciers—at least in the closing stages of the glacial period—is found in the direction of striæ in some of the valleys. Striæ were noted by the writer in 1906 in the upper portions of the Similkameen river, running northward, parallel with the trend of the valley. [2]Dawson observed striæ in the valley of Whipshaw creek, running N 45 E, or down the valley, and the same observer noted striæ in the valley of the Similkameen river about Keremeos, which had a bearing of S 35° E again parallel to the trend of the valley.

Doubtless, during the period when the ice sheet covered the whole region, the direction of flow would, to a certain extent, be influenced by the trend of the valleys, but it is generally accepted that this general glaciation was in direction slightly west of south. This is borne out by the fact that glacial erratics found in the Hedley sheet are identical with rocks found in places to the north of

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[1] I. C. Russell. 20th Annual Rep. U. S. G. S.
[2] Rep. of Progress, 1877-78, Geol. Survey of Canada.

here. This, however, is almost the only evidence, for striæ on the higher level, at least in the Hedley sheet, are unknown. It is likely that the topographic forms in these higher levels were only slightly influenced, and not greatly altered by the general glaciation, but that much of the present topography can still be referred to the pre-Pliocene peneplanation.

White silts, of probably glacial lake origin, are found at an elevation of from 3,000 feet to about 3,800 feet in the upper parts of Twentymile creek. Accepting the idea that these silts were deposits in lakes, their presence might be adduced as a further argument in favour of a valley glacier in the Similkameen valley. This, by damming the outlet of Twentymile creek, might have forced the water accumulated in the valley of Twentymile creek to find an outlet northward or eastward to Okanagan valley, and later, when the level sank below the level of this outlet, to form a temporary glacial lake in which these silts were deposited.

The after effects of the glaciation are recorded in the filling of the valley bottom with deposits of gravel. These form very thick deposits, and it is believed that they belong to the period of dwindling of the glaciers, when the streams were swollen by the melting of the ice, and laden with morainal detritus. This detritus was deposited along the course of the stream, and since the final disappearance of the glaciers, the present streams have been slowly cutting down through this deposit of gravel, successive stages of erosion being marked by the formation of benches at different levels.

SUMMARY OF GEOLOGIC HISTORY.

Palæozoic—

Deposition of the Cache Creek sediments—limestone, quartzite, and argillite—in a sea in which volcanic material were being laid down with the true sediments.

Mesozoic—

Regional uplift of the strata, either accompanied or closely followed by the irruption of the quartz diorite, with apophyses injected into the sedimentary rocks.

Irruption of gabbro into the diorite before the latter was thoroughly cooled. Consequent contact metamorphism with the formation of ore deposits.

Fracturing and intrusion of lamprophyre dikes.

Tertiary—

Post-Laramie uplift and deformation.

Irruption of granodiorite, accompanied by aplite and pegmatite dikes. Contact metamorphism and slight mineralization. Faulting on a large scale probably accompanied the granodiorite irruption.

Intrusion of andesite dikes.

Formation of Eocene peneplain.

Uplift of Cascade mountains and Interior Plateau in Pliocene times.

Erosion period.

Quaternary—

Glacial period.

Deposition of stream gravels.

CHAPTER V.

ECONOMIC GEOLOGY.

GENERAL CHARACTER OF THE ORE DEPOSITS.

All the ore deposits of the district that have up to the present been worked contain gold as the principal valuable metal, and only gold has been extracted from them. In one or two isolated places, ores of copper—which are as a rule sparingly disseminated through all the deposits—are concentrated to such an extent that a small output of this ore might be brought about; but it is not likely that, within the limits of this area, the mining of copper ores will ever become an important industry. Up to the present, no extraction of copper, or shipment of its ores, has taken place. These two metals occur in the same deposits, or the same kind of deposits. There is also a genetic connexion between the origin of the gold and that of the copper—that is to say, both of these metals occur in deposits of contact metamorphic origin, so that the discussion of one must include the other.

At the close of the year 1908, reduction of the Hedley ores had been carried on for about four and a half years, and the annual production of gold has been each year in the neighbourhood of $500,000 in value. No copper has yet been recovered, except perhaps as a by-product of the smelting of the gold ores. At and near the surface, much of the gold occurred free, and was visible in the native form, but with increasing depth its recovery became more difficult, on account of a more intimate association with the sulpharsenide arsenopyrite. This is economically the most important mineral with which the gold is associated.

The occurrence, so far as at present known, takes only one form. This form is that of irregular, ill-defined bodies, of by no means uniform gold content, lying in limestone which has been altered by contact with diorite or gabbro intrusives. The ore minerals which occur in these bodies are arsenopyrite, pyrrhotite, chalcopyrite, pyrite, and zinc-blende, occurring in relative amount in the order named.

Although the rocks of the area are seamed with faults, fissures, and dikes, none of the workable ore deposits are known to occur as lodes or fissure veins. Even where fissures occur in connexion with the ore bodies they are generally barren of gold values, and are scarcely, or not at all mineralized by sulphides, a fact which proves that this fissuring undoubtedly took place at a later period than the formation of the ore deposits. This is rather a striking feature, and places the formation of the ore bodies far back in the geological history of the region. A brief study of the conditions of these ore bodies as they exist in the field is sufficient to bring out one prominent fact. All of the known deposits of workable size are intimately associated with diorite or gabbro stocks, or apophyses from these stocks. More often, and it might be said, as a rule, hey are associated with the apophyses, but at no great distance from the stocks, and moreover, they occur only in the sedimentary rocks which have been intruded by these apophyses, and not in the igneous rocks. Although not many different ore bodies are known or worked, yet those that are, show beyond any doubt, in the author's opinion, that there is a genetic connexion between the gabbro intrusives, particularly, and the ore deposits.

From their similarity of form and identity of origin it is only to be expected that the accompanying gangue minerals would be very much alike in chemical composition. They are always those which have universally been found in deposits of contact metamorphic origin, where igneous rocks have been intruded into rocks which are eminently of a calcareous nature, that is to say, the silicates of lime, garnet, epidote, diopside, and tremolite. In lesser amount, where the alteration has perhaps not been so extreme, calcite and quartz form the gangue minerals, and, in extreme cases of alteration, a small amount of axinite is present.

For a region that has produced such valuable ore bodies the Hedley district exhibits little surface evidence of its mineral wealth, and this in spite of the many and good exposures of the country rocks. The volcanic rocks of the Red mountain contain abundant disseminated sulphides, which on oxidation impart a rusty stain to the rocks. So far as known, however, no deposits of value occur within these discoloured rocks. Contacts of the igneous rocks with the sedimentary, where pyrrhotite has been abundantly developed, also show a strong discoloration on the oxidation of the pyrrhotite; but the presence of this mineral is never a criterion of high gold values, and generally indicates low values. It is rather the unostentatious development of much arsenopyrite on these contacts, accompanied by a considerable amount of metasomatism, that has proved to be productive of the best ore deposits. The arsenopyrite is not very readily oxidized, and this, coupled with the recent glaciation which the whole region has undergone, gives an ore within a few feet of the surface, which is very little different from that 200 feet down, where the ore is certainly in its unoxidized condition. The outcrop of an ore body, however, is often marked by a thin mantle of limonite underneath the soil, but this does not run very far on the downward slope, and soon disappears altogether. It has been the experience in washing this red dirt that a great number of very fine particles of gold are obtained in the pan, but never any nuggets of even moderately large size. It is characteristic of all the ore bodies discovered that the gold is disseminated through the gangue, always in very fine particles. At times the outcrop is not covered by any mantle of limonite, and the ore body shows only a very slight oxidation on the surface. This oxidation might extend down for 8 or 10 feet, but more often at that depth there is little or no evidence of it, and the sulphides are there in their primary state. As a result of the shallowness of oxidation, or the lack of it altogether, there is no zone of enriched sulphates, and the tenor of the ore within a few feet of the surface is generally that of the ore at the greatest depth yet reached. In certain instances, where conditions have been favourable, there is evidence that there has been a leaching downward of the gold content, and concentration in pockets or troughs, but in these cases the gold alone appears to have moved, while the associated sulphides have been weathered away and not transported downward. In some of the deposits, the dip of the ore body is too slight to make this factor of downward enrichment important, but even in this case there is some evidence of it on the foot-wall. It may be taken, however, as a general rule, that there has been some leaching of the gold from the upper part of the deposit, with an increase in value downward to a certain point. How far down this point may be cannot be definitely determined until other deposits are exploited.

On account of the irregularity with which the gold values are distributed through the deposits—being high in certain spots, and almost wanting in others, often too, without any apparent reason—it would be unsafe, from a few dozen assays, to attempt to give an estimate of the average value of the ores throughout the district. Samples selected at random from the ore bodies of the Sunnyside and Nickel Plate mines are no criterion of the average values of these ore bodies, for one often gets enormously high values, and often values that are much below the grade which it would pay to work. It is only by taking the total amount of gold obtained after a mill run of a month or a year, when hundreds of tons have been treated, that a correct estimate is obtained. The published statement of the Daly Reduction Company for the year 1907 gives an average of almost $15 to the ton for 35,000 tons of ore milled. It is certain that in the early stages of mining, when surface ores were more largely used, the average value must have gone slightly above this figure. It is probable also, that where greater depth is attained, the mine owners of the region will be faced by a slight lowering of the grade, which will also be accompanied by greater difficulty of treatment. Thorough tests have not everywhere been made of the ore bodies of the district, but sufficient has been done to demonstrate that there are large quantities of low grade ore, giving a gold value about equal to the present cost of treatment. With improved methods of treatment, and better transportation facilities, much of this ore could be utilized.

DISTRIBUTION.

The productive portion of the Hedley district is at the present time confined to the region lying near the top of the Nickel Plate mountain, on its eastern slope. Here are located the two most important properties in the district—the Nickel Plate and Sunnyside mines—and these two mines have so far produced all the ore mined in the whole district. Ore deposits recently discovered, and now being prospected, are located in certain portions of the eastern slope of Twentymile creek, and it is strongly probable that some of these will turn out to be of economic value. If there are others inside the limits of this district they have not yet proved to be of sufficient importance to attract capital for their development.

If we include with the proven ore bodies those prospects that give the greatest promise of productiveness, we find that they all lie in the central and northern part of the area, and within a radius of one mile from Climax bluff. A circle, central at Climax bluff, with a radius of one mile, would cover all of the known workable ore bodies, as well as these prospects which at present look most promising. It is not meant that that circle will cover the limit of productiveness for all time, because ore bodies may later be found outside it, and undoubtedly much mineralization is now known to occur outside this limit. As regards the geological distribution of these ore bodies, it appears that they are largely confined to one of the four divisions already outlined of the sedimentary rocks. No important ore bodies have yet been discovered in the Redtop, Red Mountain, or Aberdeen formations. The lowest member of the Nickel Plate formation namely, the Sunnyside limestone- is a massive blue limestone, which has not so far proved productive, except in its uppermost portion. The remaining portion of this formation, above the Sunnyside limestone, is undoubtedly the best of the whole sedimentary series, and contains all the known ore-bodies, as well as the most promising prospects. This part of the Nickel Plate formation contains much limestone, as well as some quartzite bands, and the association of these two kinds of rocks seems to have been the most favourable for the deposition of ore bodies, hence it is of special importance.

The mere association of the Nickel Plate formation with rocks of later igneous origin is not sufficient to determine the location of an ore body. Another factor is necessary, and so far as present knowledge goes, this factor is the presence of a certain kind of igneous rock. The influence of the batholithic mass of granodiorite, much as might be expected of it from its size and generally more acid composition, is relatively unimportant in the formation of ore bodies. The diorite is less in quantity and areal distribution, but its influence is stronger. The most important igneous rock, however, and one from which the least should be expected on account of its more basic composition, is the gabbro. This in virtually every case is the igneous rock which has been the most active mineralizer, and whose history is bound up with that of the ore deposits. This is the rock, which, in the case of all the ore bodies of the Nickel Plate, Sunnyside, and Mound mineral claims, either forms the foot-wall or is otherwise closely associated with the ore bodies. Not only here, but in other portions of the district where dikes or apophyses from the gabbro mass have been thrust into the sedimentary rocks, it was noticed that there was a notable increase in the gold values obtained, over those generally found on other contacts. Whether any general rule can be deduced from this remains to be proved. At the present time it is more than a mere coincidence. Another point in this connexion, but one which has its counterpart in many other gold mining districts, is that the best ore deposits are not found in the immediate vicinity of the main stocks of gabbro, but are located generally at some distance from these stocks, though on dikes or apophyses which have been derived from them. If the source of the gold-bearing solutions were in the stocks of gabbro, these solutions seem to have travelled some distance before the gold was liberated and deposited from them in the country rocks. Further discussion of this, however, will be deferred to a later section.

MINERALOGY.

LIST OF MINERALS.

For convenience of reference, the names of the principal mineral species found in the ore bodies of the Hedley district are assembled in the following list. Other minerals have been found inside the district, but only those are mentioned which are known to be more or less closely associated with the ores. The list also contains certain elements the presence of which is known from assay, but the exact chemical combination of which with other elements is not known.

There are in all 28 species:—

Gold.
Silver.
Platinum.
Nickel.
Cobalt.
Tetradymite.
Pyrite.
Arsenopyrite.
Molybdenite.
Galena.
Chalcopyrite.
Sphalerite.
Pyrrhotite.
Quartz.
Magnetite.
Limonite.
Calcite.
Feldspars.
Pyroxene.
Wollastonite.
Amphibole.
Garnet.
Epidote.
Axinite.
Apatite.
Sericite.
Chlorite.
Erythrite.

Gold.—This is the most important mineral in the region, from an economic point of view, and for the recovery of this all the mines and prospects are being worked. It occurs here in two forms—in its primary state in the ore bodies, and in a secondary state in detrital deposits. The fact that placer gold was found in the gravel deposits of the Similkameen river, and some of its tributaries, first attracted the miner to this region. The richest of these placer deposits were found higher up the river, but gold is known to occur in limited quantity in all parts of the Similkameen river. No placer deposits are now found inside the limits of the Hedley district that are rich enough to work.

In the drift derived from the decomposition of the ore bodies, gold is found in very fine grains, and this can be followed for a very short distance on the slope below the outcrop of the ore bodies. It occurs in a dark red dirt, usually covered by other drift which completely conceals it.

In the ore bodies themselves, gold is only visible in the rock in the surface zone. Below this, while the value of the ore may not have decreased much, gold can rarely be seen. In this surface zone free gold can frequently be seen in a gangue of sulphides and lime silicates. The particles are small, but can easily be detected without the aid of a lens. It is seen to be associated either with arsenopyrite or tetrahedrite. The latter is only sparingly disseminated through the gangue, but wherever it does occur, it is generally found to be associated with [illegible] gold.

Gold is [illegible] known to occur with arsenopyrite. It becomes visible in the surface zone, where after oxidation of the arsenopyrite in which it was held, it remains as an insoluble residue, while the arsenopyrite was carried away. What the exact nature of the combination of the gold and arsenopyrite was in the primary ore is not known, but it does not appear to have occurred as a telluride. It is more likely that it may have been intimately mixed with the arseno-pyrite, and in its cleavage planes, or else it is in [illegible] in the arsenopyrite. The great difficulty met with [illegible] the gold in the stamp mill, seems to point to the [illegible] actual combination of the gold with the arsenopyrite.

The visible gold that has resulted from the decomposition of arsenopyrite is not crystalline, but is very ragged, with [illegible] projecting points. It has a dull rusty tarnish, but is quite bright when freshly cut.

The surface ores lend themselves very readily to reduction by amalgamation, but in the ores below the influence of surface alteration the treatment becomes more difficult, and only a very small per cent of the total value is obtained on the amalgamating plates. Besides the arsenopyrite, gold to a limited amount is known to occur with the other sulphides of the ore bodies. Attempts, however, to prove the relative amount associated with each sulphide were not successful. All that was ascertained from these tests was that the greatest amount of gold is with the arsenopyrite, and a much smaller proportion with the others. It was also determined that equal amounts of arsenopyrite do not carry uniform values, but that these values vary through hundreds of dollars to the ton. The amount of gold associated with arsenopyrite, pyrrhotite, sphalerite, and chalcopyrite, as far as the tests were carried, will be found under each of these minerals.

In the primary ores, the gold values vary considerably. Ores of the average value of $14 to the ton are being mined on the Sunnyside and Nickel Plate mines, but this value is the result of a careful selection of ores of a higher grade, mixed with those of lower, so as to make a uniform product from month to month. It is certain that there are large quantities of ore in the district which will only give from $5 to $7 to the ton, and this, with the present cost of treatment, and lack of transportation facilities, might only give a bare margin of profit, even in the case of the larger figure, for the present cost of extraction must amount to almost $6 to the ton.

The fineness of the gold occurring free in Hedley district has not been determined, and no estimate of it can be given.

Silver.—No native silver is known to occur within the Hedley area, though it is reported only a short distance outside. Assays of virtually all the Hedley ores, however, give a small fraction of an ounce of silver per ton; but higher values are obtained in those deposits which lie in massive limestone, where the silver probably occurs in association with galena. It is rarely, however, in sufficient quantity to make it important in increasing the value of ore.

Platinum.—In a personal communication to the author from Mr. F. A. Ross, manager of the Daly Reduction Co., the presence of platinum was referred to. Mr. Ross says that in the process of the clean-up, at the end of a month's run of the stamp mill, an unusual deposit was noticed on one of the plates, close to the lip of the mortar. A sample of this, about one pound in weight, was collected and submitted to the chemist for analysis, who reported it to yield about 0.5 per cent platinum. It was suspected that the platinum occurred, not as the native metal, but as the arsenide sperrylite.

Nickel.—The presence of this element is known in the ores of this district, and it was obtained by assay from pyrrhotite concentrates from the Sunnyside mine. The exact nature of its occurrence, however, is unknown. An amount of 0·19 per cent of nickel was obtained by assay of the pyrrhotite concentrates.

Cobalt.—Pyrrhotite concentrates also gave on assay a trace of cobalt. The presence of this mineral was also suspected in combination with the arsenopyrite, making the mineral species danaite. But it has not been actually determined as such, though the occurrence of hydrous arsenate—erythrite—on the outcrop of the Nickel Plate ore body—lends weight to this suspicion.

Tetradymite ($Bi_2(Te{\cdot}S)_3$).—Tetradymite is found sparingly in the upper parts of the Nickel Plate mine, and generally near the surface. It occurs in dark bluish crystals, which are foliated and soft, and have a bright steel grey metallic lustre on the fresh surface. This mineral was identified in a sample of contact metamorphic rock by Prof. C. H. Warren. It occurs in the massive altered limestone, which consists of garnet and epidote with much arsenopyrite. It is very often found in association with free gold, and specimens of the ore show crystals of tetradymite enclosing small particles of native gold. It has apparently no connexion with any fissures, but may be the result of secondary alteration near the surface, as it has not yet been identified in the deeper part of the mine. On the other hand, the minerals with which it is associated—namely, garnet, epidote, and arsenopyrite—show little or no evidence of surface alteration, and there is a strong possibility that this telluride may be a primary constituent of the contact metamorphic rock formed contemporaneously with the other contact metamorphic minerals. This, apparently, is the only one of the tellurides which has up to the present been identified in contact metamorphic deposits. [1]Prof. Warren in testing a small portion of the mineral got a reaction for lead, which at first led him to suspect nagyagite, but further tests gave a strong bismuth coloration, which, with the general appearance and crystallographic form, proved the mineral could only be a tetradymite, which carries some lead.

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[1] W. H. Weed, geology and ore deposits of Elkhorn quadrangle; 22nd Annual Report U. S. G. S., Part II.

Pyrite (FeS_2).—Pyrite is not as abundant as either arsenopyrite or pyrrhotite, and, because it has not been found as a general rule in association with the ore deposits, has not been as closely studied as the other sulphides. Its occurrence is not general among the rocks of the area, but its distribution is localized in certain isolated areas. In these areas, however, it becomes quite abundant. On the Bulldog mineral claim it is abundantly developed in the contact metamorphic zone of the sedimentary rocks. The contact metamorphism has here been produced by the intrusion of a gabbro porphyry, and the pyrite appears in massive form, in bunches scattered through the mass of the lime silicate rock. It also follows well-defined lines, as if filling small fissures in the altered sediments. It is also found very sparingly disseminated through the igneous rock. It is generally of a very pale yellow colour, and as a rule occurs in granular masses, without any tendency to crystallographic outline.

Arsenopyrite (FeAsS).—Arsenopyrite is the commonest and most widespread sulphide in the district. It is found in all the igneous rocks, and their dike equivalents, and also in the sedimentary rocks where cut by these igneous rocks. In the plutonic rocks it is always well crystallized, and is sparingly disseminated through them. It was observed more abundantly in narrow cracks in the granodiorite, where it appears in a gangue of white quartz, and it appears in the same way in the diorite. In the dike equivalents of these plutonic rocks, and particularly of the diorite and gabbro, it becomes much more abundant, and appears always in well formed individuals, apparently the first to crystallize. It is also an original constituent in the volcanic rocks of the Red Mountain formation. It is most abundant, however, in the contact metamorphic zone of the sedimentary rocks, where these have been intruded by the dike forms of the dioritic and gabbroid rocks. Here it occurs as disseminated individuals in well formed crystals, or else in more or less well-defined bands when the crystallization is less perfect. It appears to have been formed in this case simultaneously with the garnet, epidote, and other contact metamorphic minerals, and is associated generally with pyrrhotite, less frequently with chalcopyrite and blende. There can be no doubt that the arsenopyrite of the contact metamorphic rocks has been derived from the igneous rocks, for there is no sign of its presence in the unaltered sediments, and the transfer from the one to the other was effected immediately after the intrusion, and crystallization took place simultaneously or even slightly before the other contact metamorphic minerals. A later generation of arsenopyrite accompanies the crystallized arsenopyrite, and this appears in more or less well-defined lines roughly parallel to each other and showing a crystallization much less perfect than the above. This form is probably due to eruptive after-actions, following the igneous intrusion either before complete recrystallization or shortly after it. There is a slight difference in colour between these two kinds, the crystallized variety being white in colour, while the massive form has a very slight bluish tinge. When crystallized, the arsenopyrite is very often twinned, the twinning lines appearing as striations on the faces of the crystal. The arsenopyrite is most important, on account of its association with the gold. It has been definitely proved that gold, rarely, if ever, occurs in payable amounts, unless arsenopyrite is present in the ore in considerable quantity; but it has also been demonstrated that all deposits of arsenopyrite in this district need not necessarily contain gold in sufficient quantity to pay for working. The massive form is more often an indication of good gold values than the well crystallized form. On account, however, of the patchy nature of the distribution of the gold values, concentrates of pure arsenopyrite give very variable amounts of gold on assay. Absolutely clean arsenopyrite taken from a part of the ore body which was known to be rich, gave results of 12·38 ounces in gold and 0·78 ounces in silver per ton, also 8·36 ounces in gold and 0·06 ounces in silver. Another assay of pure arsenopyrite, which was taken from another part of the ore body, also being mined as rich ore, gave only 0·30 ounces in gold and 0·39 ounces in silver. Experiments of this nature simply serve to confirm the findings of the mine operators that the gold values are in spots, and that it is impossible to tell, except from assay, what results arsenopyrite ore will give in gold values.

Molybdenite (MoS_2).—Molybdenite was noticed in only one locality in place, namely, on the northeastern slope of Twentymile creek, about half a mile below the dam. It is here found in small fine scales of a bluish grey colour and metallic lustre, sparingly disseminated throughout the quartz diorite, near the contact of a rhyolite dike. It was also found in float of the same kind of rock in the lower part of Windfall cañon.

Galena (PbS).—Galena is of very rare occurrence indeed, and though carefully looked for, was not seen in any of the ore bodies that are now undergoing development. It has, however, been reported from a locality in Climax cañon, on the eastern slope of Twentymile creek.

Chalcopyrite ($CuFeS_2$).—Chalcopyrite is of very common occurrence in many parts of the district, but is confined to the sedimentary rocks and to the contact metamorphic zone of these rocks. It is found in small amounts in all of the Sunnyside and Nickel Plate mine workings, and in many other mineral claims. It is most abundant, however, in the massive blue limestone of the Warhorse mineral claim, on the eastern slope of Twentymile creek, where it appears to be in sufficient quantity to be mined as an ore of copper. It is never in a well crystallized form, but is always massive. It appears always in small irregular and not continuous veinlets, running through the altered sedimentary rocks. On the Bulldog and Warhorse mineral claims, these veinlets are larger in width and more persistent than in other places, but even here their length can generally be measured in inches. In the Nickel Plate ores chalcopyrite generally accompanies arsenopyrite, and in that case is seen to lie along the borders of arsenopyrite crystals. In other cases, also, it is found in the interstices between the crystals of arsenopyrite, and may on that account be one of the later sulphides to be formed in the ores. Except in the case mentioned above—viz., the Warhorse mineral claim—though widely disseminated, it is never sufficiently concentrated to make it a profitable ore for the extraction of copper. Chalcopyrite, where it occurs alone, is never associated with high values in gold. Some chalcopyrite ore obtained from the Warhorse mineral claim was concentrated on the Wiltley table and then passed through the Wetherill magnetic separator to clean out the magnetic material. The concentrate was then assayed, and gave a result of 0·20 ounces of gold per ton, with 2·30 ounces in silver. This shows the amount of gold associated with the chalcopyrite to be very low, while the silver content was much higher than that obtained for any of the other sulphides.

Sphalerite (ZnS).—Sphalerite or zinc blende has not a wide distribution and is only found in a few isolated places. In these places, however, it is important, as being associated with high gold values in the ore. It occurs in greatest amount in the Sunnyside mine in

No. 2 workings, and more sparingly in the Nickel Plate mine. It was also noted in one or two places on the eastern slope of the cañon of Twentymile creek. In all of these cases it occurs in the sedimentary rocks in the contact metamorphic zone, and not far from the igneous contact. In the Sunnyside mine it appears in well-defined bands close to the igneous foot-wall, and in general parallel to this foot-wall. It is here associated with arsenopyrite and pyrrhotite, and some chalcopyrite, and appears to be a later product of crystallization than at least the two first mentioned minerals. It also occurs both at this place and in the Nickel Plate mine in well crystallized individuals, disseminated through a gangue of lime silicate minerals. It is generally a very black metallic mineral, and from its appearance contains a high percentage of iron. Less frequently its lustre is a dark reddish brown. Attempts to obtain by separation a clean concentrate of zinc blende were not successful, on account of the small amount of material that was available. Prof. Gwillim, of Kingston School of Mines, after passing some blende ore through 80 mesh screens, ran it over the Wilfley table to extract the heavier arsenopyrite; the blende concentrate obtained was then deprived of its more strongly magnetic material, and the result was a product which contained almost entirely blende and gangue. This was assayed, giving a result of 11·38 ounces in gold and 1·20 ounces in silver per ton. The result of this test was merely sufficient to prove that fairly high values are associated with the blende, but it did not prove that these values were in the blende alone.

Pyrrhotite ($Fe_{11}S_{12}$).—Next to arsenopyrite, pyrrhotite is the most common sulphide in the whole district, and is found in all parts of the area. It is, however, not important in an economic sense, as it is never directly associated with gold values, unless arsenopyrite is present at the same time. It is very abundant in the volcanic rocks of the Red Mountain formation, where it appears disseminated through the mass of the rock. It is still more abundant, however, on the contact of the more basic igneous rocks with the older sedimentary rocks. It appears here in the sedimentary rocks in the contact metamorphic zone. As a contact metamorphic product, it is abundantly developed on the Warhorse mineral claim, where it appears in association with chalcopyrite in the limestone. It is much less abundant in the Nickel Plate ores, where the gangue consists entirely of lime silicates, than in all the Sunnyside workings, where lime silicates are not so abundantly developed, and lime carbonates are in greater proportion. Pyrrhotite never forms good crystals like arsenopyrite, though it appears to be of contemporaneous origin in the ore deposits. Instead, it appears in massive form in irregular areas, or in small particles disseminated through the mass of the contact rock. Several analyses of pure pyrrhotite, separated by magnetic concentration from some of the ore being mined from the different Sunnyside workings, gave a very constant value for gold content, and also for the silver. It was found that the amount of gold in this pyrrhotite was on an average 0·065 ounces to the ton, or \$1.30. Values as high as \$1.60 to the ton have been obtained by the Daly Reduction Company's chemist, but from \$1.30 to \$1.60 is a very narrow range indeed, and proves the gold content to be almost constant. The silver value of pure pyrrhotite was also found to be very constant at about 0.06 of an ounce to the ton. Analyses also showed that a trace of cobalt, and 0·19 per cent of nickel, were present in the pure pyrrhotite.

Quartz (SiO_2).—This mineral is of very common occurrence. It is an important constituent of the granodiorite, the quartz diorite, and the quartzite. It occurs in the form of chert or fine-grained varieties in the limestone beds. It occurs, also, as chalcedonic silica in some of the siliceous or argillaceous sedimentary rocks. It is abundant in places in the contact metamorphic zone of these sediments as a secondary mineral. In such cases, it often forms large prismatic crystals, which hold inclusions of calcite, epidote, arsenopyrite, and other minerals, and in the weathering of the calcite and associated minerals, forms an interlocking net-work of large hexagonal crystals. In the fresh unweathered rock, the formation of these large quartz crystals in the calcite gives an appearance of brecciation to the whole rock. This character is well shown in the workings of Sunnyside No. 4, and in the Exchange tunnel. As a secondary mineral in the ore bodies, it occurs in irregular areas filling interstices, or in small fractures with some calcite. It is found, also, in small fractures traversing the granodiorite and quartz diorite bodies. As an alteration product it appears in the thin section as filling small fractures in some of the garnet of the Nickel Plate ore body. Because veins with a width of more than a fraction of an inch are virtually unknown in the district, quartz has no opportunity to form as a fissure filling of any but very small size.

Its greatest development in this form is seen in the contact phase of the granodiorite, where the rock is cut by small fractures which are filled with white quartz.

Limonite ($2 Fe_2O_3+3H_2O$).—Limonite is common in the zone of surface oxidation, and is characterized by a yellowish brown appearance. It is seen in abundance in the surface gravels on the Sunnyside mine, where it forms the cementing material which unites the boulders and pebbles to form a coarse conglomerate. It has here been derived by oxidation from the iron sulphides and other iron bearing minerals higher up the slope of the hill. It is present, also, in the decomposed metamorphosed limestone, though it never goes deep into the rock. Iron compounds are very abundant in the rocks of the Red Mountain formation, and by oxidation of these, limonite is formed on the surface of these rocks, wherever they appear.

Magnetite (Fe_3O_4).—This mineral is not abundant in this district. It occurs sparingly in the granodiorite, diorite, and gabbro, and their dike equivalents, but it is rare in the zone of contact metamorphism. In the more basic plutonic rocks which contain a large proportion of titanite, it may become titaniferous, or be entirely replaced by ilmenite. It also occurs sparingly in the sedimentary rocks, and the small amount noted in the contact metamorphic zone is probably not a result of the igneous intrusion, but is original in the sedimentary rock.

Calcite.—Calcite in coarse granular form constitutes much of the Stevenson limestone, and bands of the Sunnyside limestone. A great part also of the Kingston limestone is made up of coarse white granular calcite. In the contact metamorphic rocks, it is abundantly developed either alone in coarse granular masses, or along with garnet, epidote, pyroxene, and the sulphides. In the latter case, it forms very large white rhombohedra, occurring in veins or bunches. In the ore of Sunnyside No. 1 it is abundantly developed as large white or pale greenish crystals, with well marked cleavage. These crystals hold large inclusions of epidote, pyroxene, garnet, arsenopyrite, and pyrrhotite, and give a poikilitic structure to the rock. As a very much later product, calcite occurs as a filling of very small fissures traversing the metamorphic rocks, also as a filling of the cracks of garnet. Again, as a secondary mineral, it was noticed sparingly developed in the plutonic igneous rocks, and more abundantly in their dike equivalents. In the diorite, where it was found in one or two instances as interstitial between other minerals, it has the appearance of being a primary constituent.

Titanite ($CaTiSiO_5$).—Titanite is an abundant accessory constituent in the thin sections of the granodiorite, diorite, and gabbro, and their dike equivalents. It also appears in the same way, in contact metamorphic rocks of sedimentary origin, and in consequence is frequently seen in sections of the ores. Its size is microscopic, and is never seen in the hand specimen. It appears in the thin section in characteristic wedge-shaped grains, with a brownish colour and a slight pleochroism. It is most abundant, however, in the gabbroid rocks, and in the more basic facies of the dioritic rocks.

Feldspars.—Orthoclase in the plutonic rocks of the district is less abundant than plagioclase. It is found in the granodiorite and diorite as white crystals and grains interstitial between the plagioclase and hornblende crystals. Plagioclase is abundantl[illegible]eloped as oligoclase and andesine in the granodiorite and diorite, and as labradorite in the gabbros and lamprophyre dikes. All of these plutonic rocks are also cut by small veinlets of pink acid feldspar. In the metamorphic rocks it is present as small wedge-shaped crystals of unstriated feldspar, filling small fissures which traverse the rocks in the neighbourhood of the igneous intrusion. As a metasomatic mineral, it is found in a limited amount in the igneous and metamorphic rocks with which the ore body of the Nickel Plate mine is associated. In large, clear, but undefined masses it replaces the constituents of the gabbro dikes forming the foot and hanging-walls of the ore body. Also, in idiomorphic well crystallized individuals, clear and free from inclusions, it replaces the pyroxene phenocrysts of these dikes, either by projecting in from the outer edges, or by developing in the interior of the pyroxene to form a mosaic of feldspar and pyroxene. There can be no doubt in these cases of the secondary origin of the feldspar, and the variety is very much like the adularia which is so common a product of metasomatism in the vicinity of ore deposits. If it is adularia, however, its presence is rather difficult to understand, when potash feldspars are so subordinate in quantity to the lime soda feldspars, and virtually unknown in the rocks immediately connected with the ore bodies.

Pyroxene.—This mineral, in its different forms, is one of the most abundant in the district, and is found both in the intrusive and contact metamorphic rocks. As a diallage it forms about 39 per cent of the gabbro phase of the diorite-gabbro complex. These crystals are large and well-developed, with a strong augitic habit, and have a white to very pale green colour. The composition, as worked out from the chemical analysis, is given in the petrographic description of the gabbro. In the gabbro dikes associated with the ore bodies, it has suffered some metamorphism. Thin sections of these crystals show a frequent replacement by calcite. A peculiar replacement by unstriated feldspar is also occasionally seen. In this case, wedge-shaped crystals of feldspar project from all sides into the diallage, until the whole crystal is finally replaced by an aggregate of feldspar grains. In the contact metamorphic rocks, a pale to dark green variety of pyroxene is very abundant, and has been determined as diopside. This is a magnesia-lime silicate formed by the intrusion of igneous rock into impure limestone, by the alteration of carbonate to silicate. It is found intergrown with epidote and garnet and some of the sulphides. In the thin section it has a strong resemblance to epidote, but is distinguished from this mineral by a slight difference in colour, and a distinct prismatic cleavage. It generally preserves its freshness, and when altered goes to chlorite and serpentine.

Wollastonite ($CaSiO_3$).—Wollastonite is much less abundant than any of the other lime silicates, and like them is a product of contact metamorphism. It is found sparingly in the altered limestone, particularly in the Sunnyside mine. It is difficult, in the hand specimen, to separate from tremolite, on account of its fibrous structure, but in the thin section is distinguished by a much higher extinction angle. In colour it is white, and has a vitreous lustre, while the microscope shows it to be made up of bundles of parallel fibres with frayed and broken ends. It is associated with garnet, epidote, and pyroxene, but is much less abundant than any of these minerals.

Amphibole.—Common hornblende is an essential constituent of the granodiorite, and of the diorites and its apophyses. In the lamprophyre dikes it is very abundant. A colourles variety, which analysis by Mr. R. A. A. Johnston determined to be tremolite, is common in certain portions of the metamorphosed limestone, at no great distance from the igneous contact. It is here associated largely with garnet and some pyroxene. It appears in the ore of the Sunnyside mine, and on the Warhorse and Copper World mineral claims, and always in long fibrous aggregates of a white glistening colour. Often it is in sheaf-like bundles of long slender radiating fibres, with a normal optical behaviour.

Garnet.—Garnet occurs in this district, very abundantly developed in the metamorphosed limestones. In colour it is wine-yellow to dark reddish brown, and has a resinous lustre. It is most probably the variety andradite, or the lime-iron garnet. It most commonly occurs in the massive form, yet in many places beautiful large dodecahedrons can be obtained. It is generally associated with epidote or pyroxene in the contact metamorphic zone, and with these minerals it lies in distinct bands which appear to follow the original bedding planes of the rock. It also accompanies calcite, and is then seen as small crystals embedded in large calcites. In the thin sections it is seen not only in well-defined bands, but it also appears in bunches scattered through a mass of epidote or pyroxene grains. Here it rarely shows the normal isotropic character, but more generally shows the optical anomalies peculiar to this species. This consists of feeble to strong double refraction, with a regular zonal structure, or concentric bands. It is frequently intergrown with epidote, diopside, and arsenopyrite, and sometimes holds these three minerals as inclusions. It is traversed by irregular cracks, and these are often filled with calcite or quartz.

The garnet is highly developed on the contact of diorite and gabbro, and much less on the granodiorite contact. It has been the experience in this region also, that garnet has been more highly developed in the impure siliceous limestone than in the more massive and pure varieties. It always accompanies the ore, and it cannot be said that gold values seek the garnet or epidote areas in preference to any other. Not only has garnet a wide distribution among the sedimentary rocks inside the Hedley area, but it also covers a great extent in the rocks outside it, wherever igneous rocks have been injected into the older sedimentary rocks.

Epidote.—This mineral, a silicate of lime, iron, and alumina, appears as a secondary product in the feldspars of the diorite and gabbro and their porphyries, and also of the lamprophyres. Its principal occurrence, however, is in the metamorphic zone of the sedimentary rocks, and, on account of the large amount of contact metamorphism in the district, it is very abundant. It occurs here in intimate intergrowth with garnet, pyroxene, arsenopyrite, pyrrhotite, and chalcopyrite. Attempts to show a definite sequence in the crystallization of these minerals entirely failed, for conflicting results were obtained throughout, and an apparent sequence obtained in one case was often reversed in another. Well crystallized individuals were very rarely seen, but its characteristic habit is a massive form, which under the microscope is seen to be made of a multitude of small irregular grains. It is difficult to separate from the pyroxene, but as a rule does not show such a good cleavage as the pyroxene. With garnet, in the Nickel Plate mine, it forms distinct bands which are conformable to the original bedding planes of the rock. It is also occasionally seen as the filling of small fissures traversing the contact metamorphic rocks.

Axinite.—This mineral, which is a boro-silicate of calcium and aluminium, is found in several places in the central portion of the district. It occurs in the neighbourhood of Climax bluff on the immediate contact of the gabbro stocks, and in the workings of the Nickel Plate mine. It is not widely distributed in distance in this district, nor is it found in a variety of rocks. Its home is in the sediments in the zone of contact metamorphism, and as a rule, not far away from the eruptive rock. On the northern side of Climax bluff it is found on the border of a gabbro stock in a brecciated rock, which is made up of fragments of quartzite and silicified limestone, cemented by an igneous cement of soft greenish-grey friable rock. The brecciation is doubtless due to the intrusion of the gabbro, and the axinite occurs in it in bunches from a few inches up to a foot in diameter. Also, in the Nickel Plate ore body, it appears often in segregated masses or individual crystals scattered through the rock in localized areas, and is here one of the products of contact metamorphism, induced by the intrusion of the gabbro porphyry. It has characteristically a clove-brown colour, and is always well crystallized, showing the typical acute-edged crystals, with a bladed columnar structure.

Apatite.—A phosphate of lime and fluorine. In connexion with the ores, apatite is not, as a rule, abundantly developed, but it was noticed in a thin section obtained from the ore of Kingston mineral claim, within a few feet of the contact with the diorite. It occurs in small white crystals of prismatic habit and moderately high relict, in association with garnet, diopside, and other contact metamorphic minerals.

Erythrite.—*Hydrous cobalt arsenate.*—This mineral was noted sparingly in some of the ore lying about the Nickel Plate glory hole. It is an oxidation product of some of the arsenopyrite, and only appears where the rock has been for some time exposed to the atmosphere. It is globular in form, or appears as an incrustation on the rock. In colour it is pink or peach red, and is very soft and easily broken down.

Sericite.—What appears to be this variety of mica is frequently seen in the thin sections, as an alteration product of feldspar. It is, however, not so abundantly developed in this district as in many mining districts. The feldspars of the igneous rocks associated with the ore bodies show a greater tendency to go over to sericite than those of the main bodies of plutonic rock.

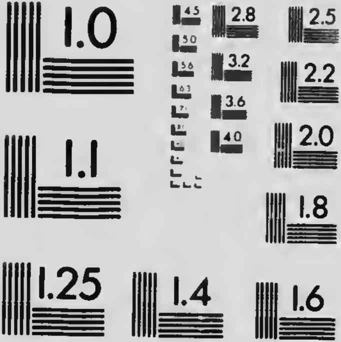
Chlorite.—Chloritic minerals form rather abundantly in some of the dike rocks which have been subject to alteration by ordinary decomposition. Chlorite, however, is rare among the minerals which make up the ore bodies.

CHARACTER OF DEPOSITS AND RELATION TO COUNTRY ROCKS.

Types.—Up to the time of completion of the field work of this district, the number of ore deposits developed and being mined was not great. The best known of these, and that first worked, and now most extensively developed, is the Nickel Plate ore body. The outcrop of this lies on the eastern slope of Nickel Plate mountain at an elevation of 5,900 feet above sea-level, or about 4,300 feet above the bottom of the Similkameen valley. Twelve hundred feet to the southeast of this and 250 feet below it, is the northern ore body of the Sunnyside mine, commonly referred to as Sunnyside No. 4. Lying 400 feet to the south of the last is Sunnyside No. 3, while Sunnyside No. 2 lies 400 feet to the south of Sunnyside No. 3. A fifth ore body, known as Sunnyside No. 1, lies on the southern border of the Sunnyside mineral claim, but it has not yet been much explored, and its dimensions are not known. The four first mentioned are the most important and best known ore bodies in the whole district, and from a study of these, deductions were drawn as to the nature and occurrence of the ore bodies of the whole camp. Other ore

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



bodies, whose dimensions and values have not yet been thoroughly proved, are known to occur on the Mound, Horsefly, Warhorse, Kingston, Metropolitan, and Florence mineral claims; but so far as known they exhibit somewhat similar characters to the four above mentioned, and are, therefore, included in the general description and classification. These four have, themselves, characteristic features and environment which place them all in the same type of ore body, so that no division need be made. This type may be described as containing ore bodies of roughly tabular form—without any well-defined walls—lying in metamorphosed limestone beds, either on the direct contact of an intrusive igneous body, or within its sphere of influence. They contain gold as the principal valuable metal, and are mined for this. They are not directly connected with any evident system of fissures, and are undoubtedly due to the igneous intrusion. They are, therefore, true contact metamorphic deposits, but of a type unique in themselves, inasmuch as they have arsenopyrite as the principal sulphide, and have no equivalent, so far as known, in North America.

Ore and Gangue Minerals and their Paragenesis.—All the minerals that have any connexion with the ore deposits have been described in detail in a previous section. Many of these, however, are relatively unimportant, while there are others which are essential constituents of every ore body. Of the latter, arsenopyrite is by far the most abundant ore mineral, and is found not only in the ore deposits, but on nearly every contact of the igneous rocks with the sedimentary. It is safe to say that no shaft has been sunk or tunnel driven on any prospect in the district which does not show mineralization to some extent by arsenopyrite.

Next in abundance, but of very much less economic importance, is pyrrhotite. This mineral is not necessarily an essential constituent of the ore bodies, and in some deposits it is wanting; but it occurs in great abundance in certain localities, especially on Red mountain, and south of the Climax cañon. Like arsenopyrite, it is found on the contacts of the diorite-gabbro rocks with the sediments, and particularly where these sediments are strongly calcareous. Its companions are generally arsenopyrite and chalcopyrite, rarely sphalerite.

Next to arsenopyrite, chalcopyrite is perhaps the most widespread sulphide, but it occurs in such small amounts that its presence is often overlooked. In the ores of the Nickel Plate and Sunnyside mines it is always present, though sparingly, and in only one or two other places does it become abundant enough to be conspicuous.

Sphalerite and pyrite are relatively less abundant throughout the whole district than the three above-mentioned minerals, and their distribution is restricted to certain ore bodies on the Nickel Plate mountain. Where they do occur, however, they are of first importance, and exceed in quantity all the other sulphides, except arsenopyrite. Like the others they are found in the sedimentary rocks in the contact metamorphic zone, and their origin is due to the same processes by which the others were introduced into these rocks.

Of the various minerals associated with the ores in the capacity of gangue, calcite has undoubtedly played the most important part. It is seldom, however, that the mineral forms as large a part of the ore bodies, where contact metamorphism has been most powerful, as it does in the less altered rock, where mineralization has been less active. Though it still remains in certain ore bodies more distant from the igneous rocks, it has been largely replaced in the process of contact metamorphism and mineralization by the five sulphides mentioned above, by various lime silicates, and by quartz. In ore bodies, such as the Nickel Plate ore body, where the metamorphism has been extreme, it has been entirely replaced in the body of the deposit, and is only found as a secondary mineral filling small fissures.

The replacing minerals, and those which now form the gangue of the ores, are all silicates of lime, magnesium, and iron, and the most important of these are pyroxene, epidote, garnet, and amphibole. There are a few others, and their occurrence has been described in another section, but they are relatively unimportant, and their distribution is not wide. To complete the list of important gangue minerals, quartz must be added.

With the exception of the pyrite, the four principal sulphides mentioned above—namely, arsenopyrite, pyrrhotite, chalcopyrite, and sphalerite—occur so abundantly, and in such frequent association with each other, that there are many opportunities of studying their paragenesis, or order of formation. These sulphides are also found in close association with the principal gangue minerals, so that the relation of each of them to these gangue minerals can readily be worked out. For the study of the gangue minerals, thin sections offer the best opportunities, but for the opaque metallic minerals, polished surfaces of a hand specimen of ore give by far the most satisfactory results. In discussing this subject of paragenesis, a three-fold division suggests itself as the simplest form of treatment. These subdivisions are: (1) paragenesis of the ore minerals; (2) paragenesis of the gangue minerals; and (3) relations of ore to gangue minerals.

(1) Among the metallic sulphides of the district, arsenopyrite always has the best developed crystal outlines, while pyrrhotite, chalcopyrite, and sphalerite rarely show any tendency to crystallographic form. Where arsenopyrite and chalcopyrite occur together, as they so generally do, arsenopyrite forms large, well developed crystals, while the chalcopyrite lies in a thin streak around its outer edges. It does not appear as if the chalcopyrite were occupying a small fracture plane along the edge of the arsenopyrite, but rather as if in crystallizing from solution the chalcopyrite was forced to take that position by the greater crystallizing power of the arsenopyrite. They would, therefore, be of virtually contemporaneous origin. If the chalcopyrite were later, and filled a fracture, we should expect, where arsenopyrite is so abundant, that occasionally the fracture might cut across the arsenopyrite crystals, and the chalcopyrite be in this; but no such occurrence was ever noted, and we are forced to the conclusion that the two minerals formed simultaneously. In the same way, when arsenopyrite, pyrrhotite, chalcopyrite, and sphalerite occur together in the same section of a hand specimen, the arsenopyrite forms large crystals of regular outline, while the other three are intergrown together, and fill the interstices between the arsenopyrite crystals. No fracturing is apparent, but the pyrrhotite (See Plate XVI), chalcopyrite, and sphalerite appear to have formed from the same solution as the arsenopyrite, and were forced to a subordinate position in the interstices, by the greater crystallizing force of the arsenopyrite. All, however, are of the same age.

In the high grade ore of the Nickel Plate mine, not far below the surface, it is highly probable that there are two generations of arsenopyrite. In thin sections of this ore, two kinds of arsenopyrite are apparent—the one the customary kind, well crystallized, and the other following well-defined lines, and without good crystallographic form. The latter is taken to be due to the same causes as the for-

PLATE XVI.

Polished surface of ore from Sunnyside mine, No. 3. White areas are arsenopyrite well crystallized. Grey areas pyrrhotite, without crystallographic outline. Dark areas ground mass of diopside and quartz.

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mer, but of a slightly later date, and fills cracks which formed on the cooling of the rock. In the same way, chalcopyrite is very occasionally seen filling minute fissures in the ore body. The second generation of these two sulphides, however, is inconsiderable in proportion to the amount that is undoubtedly of primary origin.

(2) In the case of the gangue minerals, it is difficult to generalize, for the order of crystallization which holds in one case will not hold in another. Calcite in all cases was the original mineral where the ore bodies now lie. In the immediate neighbourhood of the intrusives, however, the calcite has been entirely replaced, and none now remains. Where metamorphism has not been so extreme, as in some parts of the Sunnyside mine, much of it yet remains as an original constituent of those minerals, but the large crystals which are there formed are seen to be full of smaller crystals of garnet, grains of epidote and diopside, and the sulphide minerals. Quartz is also seen in the thin sections to be replacing the calcite. This kind of calcite, therefore, is of earlier formation than the lime silicates garnet, epidote, pyroxene, and hornblende, and also quartz and the sulphides. There is, however, another kind of calcite which is later than the above-mentioned minerals, and this is found in fissures, traversing the ore bodies, and is probably due to circulating surface waters.

Where calcite has been completely replaced, and the lime silicates formed, no definite and uniform order of crystallization can be made out. An apparent sequence in one section will be completely reversed in another, so that it appears accidental which of the four—garnet, epidote, diopside, or tremolite formed first.

Quartz is undoubtedly later than the calcite, and frequently replaces it, without replacing the garnet and epidote which formed in it. It appears to hold a fairly constant relation to all the other gangue minerals, and is one of the last minerals to have formed. It frequently fills small fissures in the ore body, and often occupies cracks in the garnet crystals, so that it can only be of later origin.

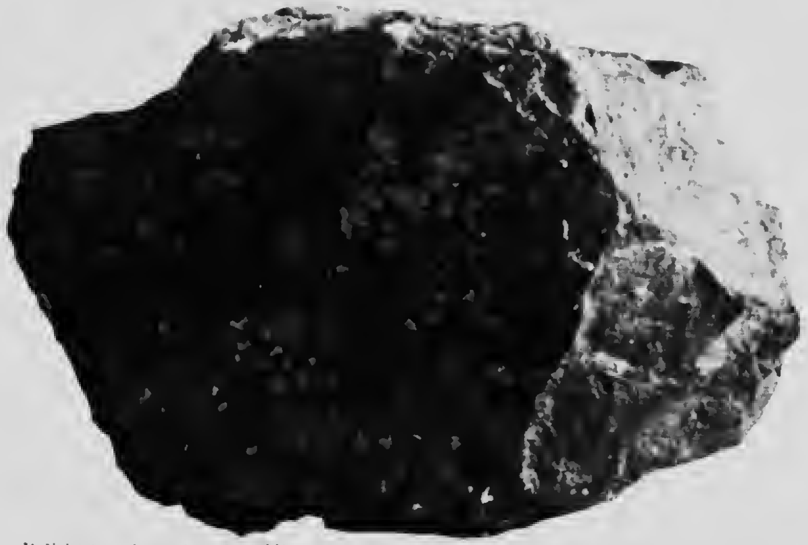
(3) Although arsenopyrite has the best crystallographic form of all these minerals, both ore and gangue, it does not necessarily follow that it is to be considered as being earlier in origin. Thin sections of arsenopyrite with this idiomorphic outline are seen under the microscope to be full of small grains of epidote, garnet, and diop-

side, and we infer that these minerals must have been formed before the arsenopyrite attained that development. Again, the borders of the arsenopyrite crystals show an intimate intergrowth with the lime silicate minerals, and polished surfaces show the arsenopyrite disseminated through a gangue of lime silicates. (See Plate XVII.) Quartz is the only one of the gangue minerals which is not included in the arsenopyrite, so that it is always decidedly later. The other sulphides, pyrrhotite, chalcopyrite, and sphalerite, while never well crystallized or holding inclusions of the gangue minerals, are seen in the polished surfaces of the ore to be intimately intergrown at least with the epidote and diopside, so that they, also, are of virtually simultaneous origin.

In summing up the paragenesis of all these minerals, it appears clear that calcite was the original mineral of the ore bodies. Some quartz was also present, as seen in the same beds where there has been no metamorphism. After the intrusion of the igneous rocks metamorphism took place, and some material was added to form the sulphides and the lime silicates. The result of this transfer, and of the heat of the igneous intrusions, was a recrystallization, during which epidote, garnet, diopside, and tremolite were formed simultaneously with arsenopyrite, pyrrhotite, chalcopyrite, and sphalerite. Some arsenopyrite and chalcopyrite were probably introduced slightly later as a second generation. Last of all, quartz was formed. After the rock had cooled again, and the ore bodies formed, a minute fracturing took place, and these fractures were filled with secondary calcite, and some quartz. In rare instances, some of these fractures contain clear unstriated feldspar as a secondary mineral, but the amount is relatively small.

Dimensions.—With the single exception of that of the Nickel Plate, the ore bodies of the district have not been explored sufficiently to give a definite idea of their general outlines. The boundaries of an ore body are defined largely by the circumstances under which it is worked, including the cost of treatment of the ore, etc. In the case of the Nickel Plate ore body, which may be taken as typical of all, its boundaries could easily be extended to greater length, provided the cost of mining and treatment could be reduced. It is possible, however, to obtain a fairly definite idea of what at present constitutes the ore body in the Nickel Plate mine, by examining a plan of the underground workings.

PLATE XXII.



Polished surface of typical Nickel Plate ore. Characteristic Nickel Plate ore showing arsenopyrite (white) disseminated through a gangue of epidote and garnet.

PLATE XVIII.

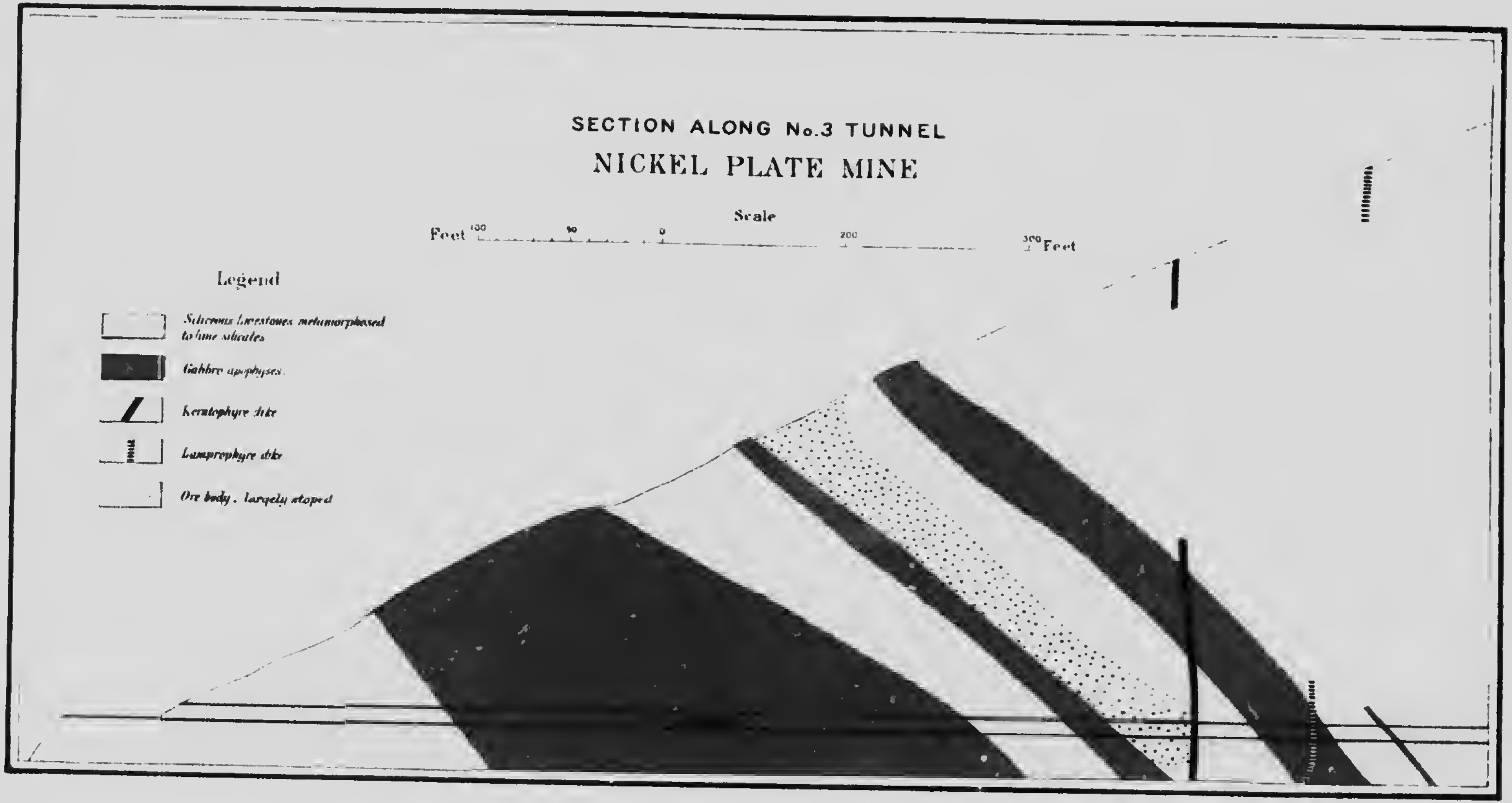
Banded structure in polished surface of Nickel Plate ore. Nickel Plate ore showing arsenopyrite (white) disseminated through a gangue of garnet and epidote, or arranged in bands along the original bedding plane of the rock.

Canada
Department of Mines
GEOLOGICAL SURVEY

Hon W Templeman, Minister. A.P. Low, Deputy Minister
R.W. Brock, Director

1910

Figure 3



Following the method used by Lindgren and Ransome in describing the geometrical relations of the ore bodies of Cripple creek,[1] the dimensions of the Nickel Plate ore body are about as follows: pitch 25° W or coincident with the dip of the intrusive gabbro which acts as the foot-wall; pitch length 350 feet as far as mined; width or thickness varying from 15 to 65 feet; greatest breadth, 125 feet. The trend of the longest diameter is roughly N 80° W.

Comparing these dimensions with the ore bodies of the Sunnyside mine, which are the only other ore bodies sufficiently developed to warrant a comparison, it is found that the pitch in the case of the Sunnyside body varies from 30° to 0, and is dependent largely on the dip of the sedimentary rocks in which the ore bodies lie. The pitch length and the breadth are variable, but, so far as known, are less than in the Nickel Plate ore body, while the thickness does not often exceed 25 feet. A striking similarity appears in the bearing of the longer diameters of the Sunnyside ore bodies, which is about N 70° W or within 10° of the strike of the Nickel Plate ore body. It is not to be expected, however, that all the ore bodies that may later be found in other portions will conform to this strike, but it is to be expected that the Sunnyside and Nickel Plate ore bodies, the most distant of which are separated by not more than 2,000 feet, and have similar geological environment, should have some uniformity to trend. While this direction does not coincide exactly with the strike of the major fault planes of the district, it is parallel with certain fracture zones of lesser magnitude, but perhaps of earlier origin.

Boundaries.—As before indicated, the boundaries of all these ore bodies are, in general, determined by commercial factors, that is to say, the gold content dies out from a good workable quality into ore which is of too low a grade to give profitable returns. This is the case, as a rule, on both the upper and the lateral boundaries; on the lower or foot-wall side, there is often a sharp and well-defined boundary. In the case of the Nickel Plate and Sunnyside No. 3 ore bodies, this foot-wall is the gabbro intrusion, which was the cause of the contact metamorphism and of the primary mineralization. Through secondary enrichment, the igneous foot-wall may in favourable localities contain workable ore, but as a rule the values in it are low, and the boundary of the ore body is the plane of contact

[1] Geol. and ore deposits of Cripple creek, Prof. Paper 54, p. 206.

between the igneous and sedimentary rocks. There are other cases (for example in Sunnyside No. 2) where the ore body is not in direct contact with the igneous intrusive, a stratum of the sedimentary rocks acting as the foot-wall. This stratum undoubtedly proved impervious to ore bearing solutions, which followed more easily altered and porous beds.

There are other instances in which certain ore bodies have been proved to have well-defined and clear cut walls, where there has been secondary enrichment by downward movement along the foot-wall to a point where this is intersected by a cross-cutting dike. This is illustrated in the case of the Nickel Plate ore body, when a lamprophyre dike and a porphyry dike, both cross-cutting the igneous foot-wall, have formed a trough with impervious walls, through which descending waters could not percolate. The same conditions are found in other portions of the district, and seem to indicate that after the formation of the primary ore deposits concentration took place, so that what may have been originally lean ore has been so enriched as to become of commercial value. While the presence of a later dike as the boundary of an ore body is not absolutely essential to a good commercial deposit, the influence of such, in the surface zone at least, should not be overlooked or underestimated, in determining the location of workable ore in a locality which otherwise might only have contained lean primary ore of low grade. At the same time, it must also be remembered that such conditions are only likely to be a factor in the early stages of mining in the region, and it should not be expected that enriched ore bodies, retained by impervious cross-cutting dikes, will recur at unlimited depth, or even below the influence of surface waters. There we should expect to find the ore bodies in their primary state—true contact metamorphic deposits formed by the effect of igneous intrusion, and with vague undefined boundaries.

Persistence.—In a district as little developed as this, and containing a type of ore bodies which in other parts of the world has the reputation of having been notoriously erratic and uncertain, a discussion of the persistence of the ore bodies cannot escape a vagueness inherent to the subject. So far as development and experience show, deposits of this general type occurring on actual contacts are very bunchy, and cease in depth. There are exceptions, however, and where the ore is uniformly distributed through the contact zone

—as at Cananea, Mexico, and Phœnix, B.C.—there is no theoretical reason why the primary ores should not persist down to the igneous source, and if the theory of genesis is true, there is no reason why they should become lower in grade. In the case then, of the Hedley deposits, their persistence in depth depends entirely on the correctness of the view with regard to the origin of the igneous rocks with which they are connected. It is believed that the gabbro dikes and sheets which either form the foot-wall of the ore bodies on the Sunnyside and Nickel Plate mines, or are closely associated with them, are merely apophyses from a larger stock-like body of gabbro lying on the western slope of the hill. If these then are followed down to their source they will be found to pass into the stock at a depth dependent on the dip of the dike or sheet: and at this point the ore bodies must cease vertically.

Apophyses of diorite have in several instances been traced to their source in the parent stock, and while actual surface exposures of gabbro apophyses have not likewise been so traced, the geological relations of each of these rocks to the sediments are identical, while the texture of the larger gabbro apophyses can hardly be distinguished from that of the stock. The mineralogical composition too, of stock and apophysis, is the same, so that it is almost certain that the one has its source in the other. Evidence will be produced in a later section to prove that the origin of the deposits is bound up with that of the igneous rocks, so that ore bodies connected with one of the apophyses will persist only as long as they persist, and will cease when they pass into the main stock. Taking dip and strike, therefore, of any particular ore body, its maximum possible length can on this theory be calculated. Whether it will persist through the whole of this length cannot be predicted, but its maximum length is limited. It is quite true that up to the present time no individual ore body has been mined out on its downward extension, but it is also true that, as depth is attained, the treatment of the ores becomes more difficult, showing that the relation of the gold to the sulphides is much more intimate. It cannot definitely be stated whether, as depth increases, difficulty of treatment will be accompanied by a lowering of the grade, because mining has not yet gone deep enough; but once through the zone which is influenced by surface waters, there is no theoretical reason why the values should not remain constant down to the igneous contact.

The question again arises, with regard to the values in the ore body, whether in the primary ores—that is, those which have not been enriched by descending surface water but are simply the result of contact metamorphism—the values will be high enough to repay the cost of extraction. Any statement on this point would merely be an opinion, and might not be correct. Mining operations have not yet gone deep enough, so that it could be said for certain that the zone of influence of surface waters had been passed through; and further operations only can settle the question.

Relation to Bedding.—It cannot be laid down as an inflexible rule that the tabular masses of ore of this district lie parallel to the bedding planes of the enclosing limestones, but it is true that of the known ore bodies the proportions that are in parallel alignment with the bedding planes are in excess of those which are not. In formulating a general rule in this connexion, it would be safer to say that the dip and strike of the ore bodies are controlled by the dip and strike of the igneous intrusives, and these are parallel to each other.

In spite of the extensive alteration undergone by the limestones in the vicinity of the igneous intrusives, traces of the original bedding planes can generally be identified without difficulty. Where the alteration has been extreme, as in the case of the Nickel Plate mine, the actual lines of division between the different strata have been obliterated, and unless examined in detail, the whole ore body appears massive. It appears, however, on closer examination that traces of the original bedding planes are still preserved in the banding, resulting from an alternation of garnet and epidote bands. The garnet bands, in particular, follow well-defined lines in the mass of green epidote or diopside, and these bands coincide with the original planes of stratification. The general uniformity of dip throughout the greater part of the district is also a great aid in identifying the original stratification planes in restricted localities. On the Nickel Plate mountain, the dips of the sedimentary beds vary from about 10° to 30° W, and the dip of the ore bodies is also all within the limit of those figures. Sunnyside No. 2 ore body exactly coincides with the bedding planes of the limestone. These dip at an angle of 10° to the west, and the ore body follows one of the limestone strata, while its foot-wall is a stratum of white crystalline limestone. It is noticeable, also, that in this ore body, sphalerite, which is here very abundant, forms a distinct band a few inches in thickness, which is parallel to the bedding planes of the limest ne.

In the Nickel Plate mine the ore body does not follow continuously the same stratum of mineralized limestone, but cuts across the beds at a sharp angle, and passes from one bed to another, as it goes downward. This is due to the fact that the intrusive gabbro, which is the foot-wall of the ore body, has not been injected exactly along one of the bedding planes of the limestone beds, but cuts across them at a sharp angle. The dip of the gabbro is from 25° to 30°, while that of the sedimentary rocks is from 16° to 20°. The ore body follows the igneous rock, so that in the mining of it the operations will follow along one bed for some distance, until the ore becomes low grade, then a jog will be made to a lower bed, and that followed until it also passes into low grade rock. The result is that the hanging wall, if it could all be seen, would appear as a series of inverted steps, with wide flat spaces, and short jogs at right angles to the plane of these.

The principal reason why the ore bodies of the region generally conform to the stratification of the sedimentary rocks is found in the fact that most of the apophyses from the gabbro stock have been injected into the sedimentary rock along the division planes of these rocks. This was the natural and easiest path for these intrusives to follow, and especially on the eastern slope of the mountain, where all the strata dip toward the gabbro stock. For this reason the same stratum generally overlies the intrusive rock throughout its length, and if this particular stratum held an ore body in one part there is no reason why this ore body should not continue in that stratum.

If, however, the gabbro intrusives cut across the dip of the sedimentary strata, we should rather expect the ore body to lie close to the gabbro, only so long as the composition and texture of the sedimentary strata through which they cut remained constant, in a vertical direction. But if there were variations in the composition and texture of the strata through which the gabbro intrusive cut, then it would be reasonable to expect interruptions in the cont[illegible] of the ore body. In other words, ore might be confined to a ce[illegible] bed for some distance, and then die out, while the succeeding bed on the contact would be barren throughout. In such a case, an alternation of beds might mean an alternation of rich and barren bands, and a lack of persistence of the ore in any one of these bands.

Relation to Fissures.—Large fissures as passages for primary ore bearing solutions in the Hedley district are not of great importance. Considerable fracturing and fissuring accompanying orogenic movements have taken place at different periods in the geologic history of the district, but these events were later than the intrusion of the gabbro, and consequently later than the formation of the primary ores. From the great lack of any mineralized fissures connected with the gabbro intrusion it would appear as if the sedimentary rocks of the district were almost undisturbed, and had suffered little deformation before the intrusion of the gabbro. Naturally, during the intrusion of the diorite and gabbro, some fissuring must have taken place, but this appears to have been on a minute scale, and not sufficient to form large and important trunk channels for the ore bearing solutions. Following these intrusions, orogenic movement opened some fairly large fissures and developed some fault planes, but it was so long after, that the intrusive rocks were quite cold, and deposition of ore had entirely ceased.

The fissures that were available as channels for ore bearing solutions were, with a few exceptions, very minute indeed, so that we only find some of the primary sulphides filling short, narrow, and irregular cracks in the contact metamorphic zone. There are numbers of those small narrow cracks in some, but not all of the ore bodies, and these are often found to be filled with secondary quartz. The period when some quartz was introduced into these cracks was the same as when some of the primary sulphides were introduced, or not very long after the intrusion of the gabbro. Other quartz, which fills small fissures, is of much later origin. The contemporaneity of the quartz with chalcopyrite, blende, and pyrrhotite, is shown in the polished surfaces of some of the ores, where these minerals are all intergrown with each other, and they either fill interstices between arsenopyrite crystals, or small fissures in the ore. It has been found impossible to account for the ore bodies being restricted to certain portions of the contact metamorphic zone, and the localization of the values in these bodies. It may be, however, that previous to the intrusion of the gabbro, there was widespread fissuring on a minute scale in a zone where the ore bodies are now located, but that much of this fissuring was obliterated by the recrystallization of the contact metamorphic minerals, following the intrusion of the gabbro.

Since the formation of the primary ore bodies there has been extensive fracturing and fissuring, acompanied in places by the formation of large faults. These phenomena have already been discussed in a previous chapter. These faults and fissures are not confined to any one portion of the district, but are distributed over all of it, though apparently most abundant on the Nickel Plate mountain. They strike in various directions, but with a tendency to be most strongly and abundantly developed in certain directions. The most important of these directions is N 30° E, and along this line many of the topographic features of the district are aligned. Fissures with this bearing are abundant in Sunnyside No. 2, and are well marked in the Nickel Plate mine. Less important directions are N 45 W, N 70 W, and N 60 E, and along each of these lines are many small fissures, and some large faults.

It is obvious that the determination of the date of this major fissuring, relative to the formation of the ore bodies, is of great economic importance, for if the fissures were formed previous to the ore deposition, then they would be expected to be associated with ore to a depth as great as their own; while if they are later than the ore deposition, then their influence on the ore bodies would only be confined to the surface zone, or where surface waters were circulating, resulting merely in the re-arrangement of the ore minerals. In the latter case, the economic importance of the fissures would not be as great, and would cease when the surface zone was passed through.

From a study of the contents of these major fissures, it is clear that they must be referred to a date later than the formation of the primary ores. Even when they cut the existing ore bodies, they contain in themselves no ore minerals which can be said to have been introduced at the time of the formation of the origina' ore bodies. Generally, they are merely filled with barren calcite or c ey matter, and the small gold value they contain can be readily a ounted for by the action of surface waters passing through the ore bodies.

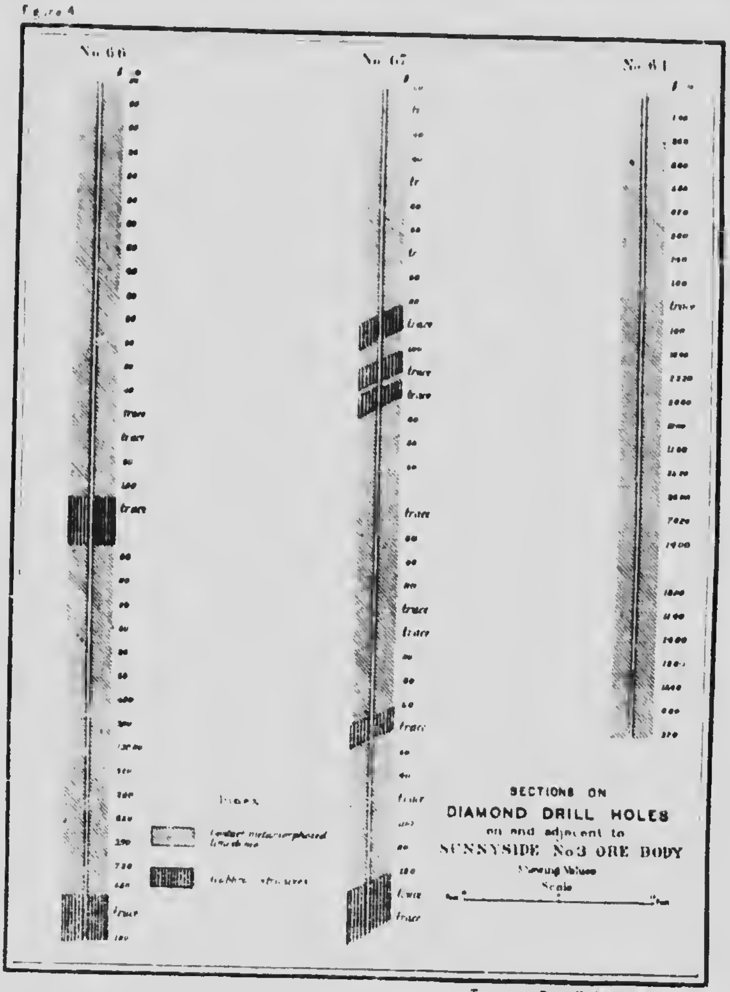
These fissures, however, become important factors where they cut pre-existing ore bodies in the zone of surface waters. Here they have been useful by allowing a free and easy circulation of surface water in transporting and re-arranging the gold values, so as to concentrate them in certain localities. By the help of these, it is conceivable that primary low grade ores would become so enriched as to bring them up to a grade that could be profitably mined. And it is a fact that where these fissures are strong and abundant in the surface zone, there the values are raised to a degree above the average grade of the ore body, where there are few or no fissures.

As in the case of the larger fissures and fractures, all the faults that have been studied are of more recent date than the formation of the ore bodies. While none of the ore bodies now being worked are known to be faulted in any degree, the above conclusion was arrived at by observation of the relation of the faults to certain planes of fracturing which cut the ore bodies, and are later than them. Therefore it is to be expected that though no instance is yet known of a faulted ore body, there is every possibility of such being discovered in the future.

In conclusion, it may be said in regard to fissures, that because the majority—and those the major ones—are later in date than the formation of the ore bodies, they are relatively unimportant economically in the deeper zone, but that in the surface zone they have become useful as channels for circulating waters to concentrate the values in certain localities, thereby raising the grade of the ore. The faults, also, are of later age than primary ore deposition.

The very common occurrence in regions of contact metamorphic deposits, of a swarm of quartz veins in association with the igneous intrusions, does not hold in the Hedley district. There are no quartz veins inside the district, other than some small irregular stringers which are connected with the intrusion of the granodiorite, and hardly any are known within a radius of 8 or 10 miles of here. Certainly none occur within the sphere of influence of the diorite-gabbro rocks, a circumstance which is probably accounted for by the low silica content of these rocks. That there was a transfer of some silica from these rocks to form the contact minerals is very probable, but it is also believed that much of the silica present in the lime silicate was native to the intruded rocks.

Distribution of Values.—The distribution of the gold values throughout the contact zone is general, and in the ore bodies themselves, erratic. Proof of each of these statements is obtained from the records of very extensive diamond drilling, performed by the Yale Mining Company on their various claims. Through the courtesy of the manager of the company, Mr. F. A. Ross, access was obtained to some of these records, and much instructive information obtained thereby. Three of these records are here reproduced. In every case the drill core was carefully drawn up and boxed, and



To accompany Reports Nos 1093 and 1094 (Bedley)

assays were made at every 5 feet of a portion of the core. No. 66 is part of the record of a drill hole put down at an angle of 25° to the east and directly across the dip of the sedimentary rocks.

No. 67 is another record of a vertical drill hole put down in sedimentary rocks which dip at an angle of about 25° to the west. No. 64 is the record of a drill hole put down through the Sunnyside No. 3 ore body, at an angle of [illegible], almost parallel to its pitch, and about 15 feet above the gabbro foot-wall. All of these are on the same claim, No. 66 being about 120 feet north of No. 67, and running at the bottom into the Sunnyside No. 3 ore body. The figures indicate the values in dollars per ton of the portions of core assayed.

Numbers 66 and 67 pass from one end to the other, through sedimentary rocks that have been completely metamorphosed by intrusions of gabbro apophyses, and some of these apophyses appear in the section. The records show the wide distribution which the gold has throughout the contact zone, even though the value rarely exceeds 80 cents to the ton. It is noticeable that wherever the gold values exceed that figure there is a sheet of gabbro underneath. Both No. 64, and the lower part of No. 66, traverse the ore body, and the values show the great variation in gold content in very short distances. In these drill holes it is impossible to account for the great localization of values in certain places. No. 64 starts in low grade rock which overlies the ore body, and at the lower end it passes out again into low grade rock on the opposite side.

Relation to Igneous Rocks.—Little importance can be attached to the many small dikes of lamprophyre, andesite, rhyolite, and quartz porphyry, as far as contact metamorphism and mineralization are concerned. Their size is generally much too small, and in the majority of cases the sedimentary rocks which they cut had previously been metamorphosed to such an extent that any additional metamorphism these dikes might have induced could only have been slight, and is not now noticeable. As previously indicated, however, these smaller dikes are important in the surface zone, not from their composition or power of alteration, but from the fact that in certain instances they have acted as dams to form basins in which enrichment of the ore bodies has taken place. In such capacity, therefore, the texture only of the dike would be important, and those with fine grain and close compact texture would be more effective than those which are loose and less impervious. The soft greenish andesite dikes are too porous to form an effective barrier for circulating solutions, but certain dense black lamprophyres, and the so-called quartz porphyries are impervious enough for this purpose.

Granodiorite lying in the bottom of the Similkameen valley is the last in age of the great igneous intrusions of the district. Having been erupted after the sedimentary rocks had been widely intruded and metamorphosed by the different stocks and apophyses of the diorite-gabbro complex, it is difficult to estimate the amount of alteration that should be attributed to the granodiorite. From a study of its contacts, however, which are always well exposed, evidence has been obtained to show that, in proportion to its size, the granodiorite has effected much less contact metamorphism than the diorite or the gabbro. Like the other igneous intrusions, on the other hand, the contact metamorphism it has effected has been apparently greater in the impure siliceous limestones, or the interbanded quartzites and limestones, than in the massive limestones of the Nickel Plate and Redtop formations. Into the latter there has been little transfer of material from the igneous to the sedimentary rocks, but the limestones merely become crystalline, or change to course marbles of crumbling granular texture. Where the limestones were thin bedded and impure, and interstratified with quartzites and argillites, contact metamorphism has been more marked, and the resulting rocks are dense and flinty, and of white, red, or dark green colour. These are seen under the microscope to contain much epidote, some garnet and chalcedonic silica, and small crystals of pyrite are scattered through them. The most important addition to the sedimentary rocks has been silica. The other elements which go to make up the contact metamorphic minerals could readily have been native to the intruded rocks, and the heat of the igneous intrusion merely served to rearrange them in different combinations. The mineralizing action of the granodiorite has not been of great importance in the formation of ore bodies. Though some values in gold are obtained in certain parts of the granodiorite contact, no notable mineralization has taken place that could be attributed entirely to granodiorite, and not to diorite or gabbro intrusives, which are found in the immediate vicinity. In general, it may be said that apart from silica there has been little transfer of material from the granodiorite, and, except perhaps in isolated localities, none whatever of the metals.

To the rocks of the diorite-gabbro formation must be conceded the most important position, as far as influencing mineralization and the formation of ore bodies is concerned. No contact of these rocks with the sediments can be examined without showing convincing proof of this, and there can be no doubt that the formation of all the known ore bodies of the district is intimately associated with the intrusions of these rocks. These rocks are the oldest eruptive rocks in the district, and they occur principally in the northern half, in distinct stock-like bodies, and in a great many apophyses from these bodies. In this portion of the district lie all the known ore bodies, and those prospects which show the most promising indications of developing ore bodies.

The diorite-gabbro formation contains two distinct types of rocks which are closely related to each other in origin, and are also connected by transitional types. For the present purpose the transitional types may be excluded as being of very limited distribution, and only the two main types will be considered, namely, diorite and gabbro. The former is a dark rock compound essentially of plagioclase and hornblende, with lesser amounts of quartz; while the latter is a white rock, consisting of plagioclase and pale green pyroxene.

These rocks are intrusive into the Nickel Plate, Red Mountain, and Aberdeen formations in great quantities, but in the Redtop formation there are only small dikes of porphyritic diorite and apophyses from the diorite stocks. The contact metamorphism has everywhere been very marked, but as in the case of the granodiorite, certain kinds of sedimentary rocks have suffered more than others. The massive Sunnyside limestone has been comparatively little affected, while the overlying siliceous limestones and interbanded limestones and quartzites have been thoroughly altered to a mass of epidote, garnet, and pyroxene. Only where the massive limestone comes in direct contact with the stocks, as it does on the eastern slope of Twentymile valley, has there been much contact metamorphism. Here the lime silicate minerals have been developed on the immediate contact, and a short distance from it; and at the same time irregular masses of the limestone have been completely replaced by silica, resulting in the formation of a dense grey rock of flinty nature, which is speckled with small crystals of arsenopyrite.

In the siliceous limestones, and the interbanded quartzites and limestones, particularly in the middle portion of the Nickel Plate formation, the actions of both the diorite and the gabbro have been to some extent identical. Near the larger igneous bodies, the alteration has been great. South of Climax bluff, a metamorphic area shows very large crystals of quartz, garnet, calcite, and epidote developed close to the gabbro. The quartz forms crystals up to three-quarters of an inch in diameter. Dodecahedra of garnet exhibit faces ½ of an inch in diameter. Epidote occurs in radiating green crystals. All these are embedded in crystalline calcite. On weathering, the calcite disappears, the garnet and epidote fall out, and the quartz remains, forming a net-work of interlacing prisms. In the same beds, on the eastern slope of Nickel Plate mountain, quartz is not so abundantly developed, but the metamorphic rock is a dense mass of epidote and garnet. These form well-defined bands, which coincide with the original bedding planes of the rock, and these bedding planes have been more or less obliterated.

In the Aberdeen formation, which consists largely of argillites and quartzites, with fewer limestone beds, the metamorphism is less intense, though here also, a wide zone of contact metamorphism with less mineralization is apparent on the contacts.

Comparing the effect of the diorite and the gabbro on the sedimentary rocks, the main points of similarity are quite evident. These consist in the powerful influence which each of these rocks has had on the sedimentary rocks, and in the alteration taking the form of the formation of epidote, garnet, pyroxene, amphibole, and some of the sulphides. Though each of them is known to have arsenopyrite, pyrrhotite, chalcopyrite, and blende in the contact metamorphic zone, there appears to be relatively more pyrrhotite and chalcopyrite found on the diorite contact than on the gabbro, while blende appears to favour the gabbro rather than the diorite. Arsenopyrite is common to both, and cannot be said to favour one contact more than the other.

It has been shown that on the granodiorite contact there has been a transfer of silica into the sedimentary, without much accompanying migration of the sulphide-forming metals. On the other hand, the contact metamorphism accompanying the rocks of the diorite-gabbro formation has been more marked, probably because there has been a much greater transfer of material. The amount of silica transferred by the diorite-gabbro appears to be about equal to that transferred by the granodiorite, but on every one of the diorite-gabbro contacts, arsenopyrite, pyrrhotite, and chalcopyrite have been formed in quantity, and these could only have come from the igneous rock. These minerals do not form in such quantity on the granodiorite contact.

The difference in the effect produced on the sedimentary rocks between the granodiorite and the diorite-gabbro may be due to physical rather than chemical factors in the igneous rocks—that is to say, to the heat evolved by each of them, and to contained mineralizers. In the case of the granodiorite, we have now exposed in this district the actual roof of the batholith, which here never reached the surface, though it may have been near it. By the time it reached its present position it was slowly freezing and losing the power to metamorphose the overlying rocks, and was becoming too viscous to send off many apophyses. The diorite-gabbro magma, on the other hand, must have been much hotter and more fluid. The contacts which we now see were not the roof contacts, but the lateral contacts, which must have been subjected to the heat of the magma for much longer periods. That the diorite-gabbro magma also was not viscous, but extremely fluid, is proved by the apparent ease with which it penetrates the sediments, the distances which the apophyses can be traced, and the great number of these, which many times exceed those of the granodiorite. Considering chemical composition of the magma alone, we should expect the granodiorite from its greater acidity to have much greater power to metamorphose than the diorite-gabbro rocks, but in spite of this, the reverse is true.

An interesting and important point, which also has an economic bearing, is the fact that all the ore bodies that have up to date been worked, lie on or near the contact of gabbro intrusives. The Nickel Plate and Sunnyside ore bodies lie in a portion of the district where the gabbro intrusives are more abundant than anywhere else, and these are the most important ore bodies, and have, to date, been the most productive. The geological map of this part does not show all the gabbro intrusives that are known to occur; but besides those which are mapped, there are many which are too small to appear on the map. The accompanying Figure 5 is a section in detail across the mountain at right angles to the strike of the rocks, and

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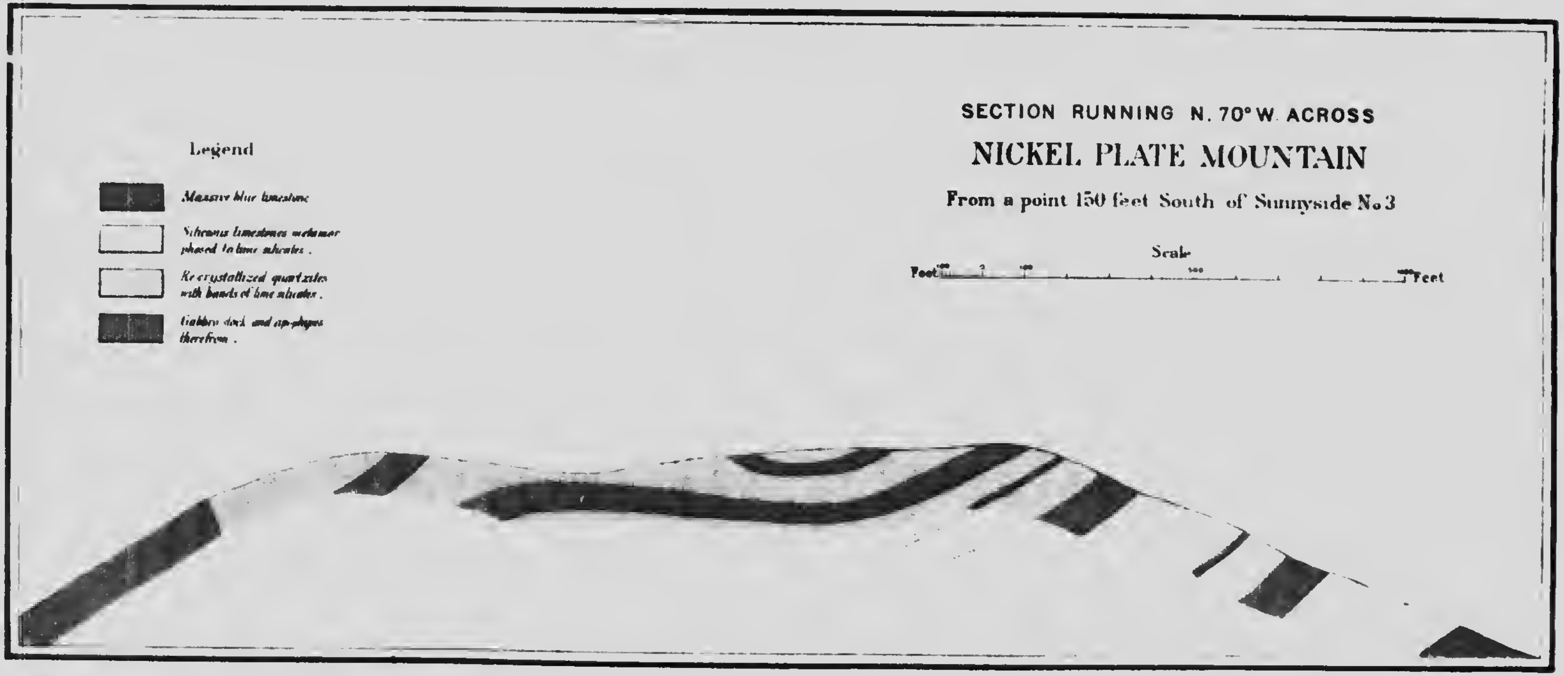
Figure 5



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To accompany Memoir No 2

shows the relation of the gabbro intrusives to the sediments which they cut. In the case of the Nickel Plate ore body, and Sunnyside No. 3, a gabbro intrusive forms the foot-wall, and the ore bodies rest directly on it. Sunnyside No. 4 has not been sufficiently developed to show the relationship, but in Sunnyside No. 2, the ore body lies between two sheets of gabbro, not directly on the lower one, but only a few feet above it, on a stratum of white crystalline limestone. A low grade ore body in the Nickel Plate mine, which is not at present being worked, lies below the ore body which is now being mined, but on top of a large sheet of gabbro, and below the one which forms the foot-wall of the upper ore body. In other cases, on undeveloped claims where higher values than usual in gold have been obtained, a short examination of the neighbouring rocks showed the presence of a gabbro intrusive cutting the sedimentry rocks in which these values were found.

The size of the gabbro body appears to have no relation whatever to the richness of the ore connected with it. The rich Nickel Plate ore body lies directly on a small gabbro intrusive, only about 6 feet in thickness, while below this is a much larger gabbro intrusive, of apparently similar composition, over 100 feet in thickness, which has on its upper side a much lower grade ore body. Several other gabbro intrusives in the immediate neighbourhood, some large and others small, have no ore body at all connected with them, though traces of gold may be obtained.

The above facts are very significant, but before any general rule can be established with regard to the genetic relationship of ore bodies to gabbro intrusives, much remains to be done in the study of yet undiscovered ore bodies. Recent developments seem to indicate that the diorite itself may also have been influential in the formation of ore bodies, but these occurrences have not been sufficiently developed to base any conclusions on. At present, it is safe to say that the diorite-gabbro formation has been the main factor in ore formation. Of the two main types of rocks which make up this formation, the gabbro, as far as present development has gone, seems to have been more potent than the diorite.

Relation to Sedimentary Rocks.—The problem of determining the geological formation to which the ore bodies of the district belong is not a very difficult one, even where metamorphism has altered the original texture and composition, and obscured much of the structure. The sedimentary rocks have not suffered much deformation from orogenic disturbances, and over the greater part of the district they preserve a striking uniformity of dip and strike, consequently it is not difficult—if certain strata are too much metamorphosed to be easily recognized—to follow out these strata to a point where their original characters are not obscured and they can be identified.

At the present time, the Nickel Plate formation contains all the known ore bodies, as well as those prospects which are being most actively developed, on account of their promising character. This formation, as previously described, has a thickness of about 900 feet. It consists, at the base, of the Sunnyside limestone member, 300 feet in thickness. At the top is another massive limestone bed called the Kingston limestone. Between the two beds lies a series of impure limestones and quartzites, which are often interstratified with each other in narrow bands. Neither the Sunnyside limestone member, nor the Kingston limestone, have yet been proved to contain gold ores in paying quantities, but the latter holds some promising copper ores on the Warhorse mineral claim, on the eastern slope of Twentymile creek. The central division of the Nickel Plate formation holds the Nickel Plate ore body and the three ore bodies on the Sunnyside claim, and most of the promising prospects of the district are also found in this horizon.

What determined the location of the ore bodies in this part of the Nickel Plate formation is not immediately apparent. Certainly, one should expect both from its character and location that the Sunnyside limestone would be as favourable for the formation of ore bodies, if not more so, than the impure limestones above it, but no ore bodies are yet known in it. It is evident that the Sunnyside limestone is more resistant to alteration by contact metamorphism than the impure and banded limestones, and this may be due to the fact that the banded limestones offer more and better channels along the bedding planes for emanations from the intrusive rock. For the same reason, these impure banded limestones were more easily and thoroughly mineralized than the more massive compact Sunnyside limestone.

Passing upward in the middle division of the Nickel Plate formation, quartzite bands become more abundant in proportion to limestone, and at the same time increase in thickness. When we pass into these quartzites we at the same time pass out of the productive portion of the formation, for quartzites are very resistant to contact metamorphism, and are consequently sparingly mineralized.

As in the case of the relation of ore deposits to the igneous rocks, it would be unsafe to generalize, from the information we have, on the relationship to the sedimentary rocks. All we can say is that the central division of the Nickel Plate formation has proved the most productive up to date, and other ore bodies should be found in it; at the same time it cannot be denied that there is a strong possibility of finding ore bodies in other formations where we know that the same conditions can be duplicated.

GENESIS.

Evidence.—Much of the evidence in regard to the origin of the ore deposits of this region has been already given in preceding sections, but it will be as well to re-state it here, and bring it into more compact form, before giving the conclusions derived from it.

It has been shown that after the deposition of the Cache Creek sediments, these were uplifted and intruded by the rocks of the diorite-gabbro formation. These igneous rocks were intruded in the form of stocks and dikes, and everywhere penetrated the overlying sedimentary rocks, producing important contact metamorphism. This intrusion took place in early Mesozoic times, and though it includes rocks of two different kinds—namely a diorite and a gabbro—they were erupted at such closely consecutive periods that they may be considered as making one intrusion.

The result of this intrusion was the metasomatic development in the intruded rocks of quartz, garnet, epidote, diopside, tremolite, and other lime silicates, accompanied by much arsenopyrite, pyrrhotite, chalcopyrite, and sphalerite. The effect on beds of different composition was various. In quartzites and argillites, the metamorphism was comparatively slight, on massive limestone it was more effective; but on thin bedded impure limestone, or interbedded limestones and quartzite, the effect was most pronounced, resulting in the complete elimination of the calcite and development of the lime silicates.

During this intrusion, also, there was considerable addition of material to the contact zone from the igneous rocks. Undoubtedly some silica was introduced, and at the same time, oxide of iron, copper, zinc, sulphur, and arsenic in sufficient quantity to form here and there notable deposits of arsenopyrite, blende, chalcopyrite, and pyrrhotite. All of these sulphides are unknown in the sedimentary rocks at a distance from the igneous intrusives. Other additions received by the contact zone were small quantities of boron, which went to form axinite, and it is believed that the gold was also introduced at this time. Assays made of the intrusive gabbro, associated with the ore bodies of the Nickel Plate and Sunnyside mines, indicate the presence of gold in varying amounts. As a rule, these are merely traces, but occasionally a sufficient amount is present to form ore. In the latter case it is certain that the presence of the gold is due to enrichment from the overlying sedimentary rock, and one can never be absolutely certain that all of the gold could not be referred to the same source. This argument, therefore, must be used with some care.

The intimate intergrowth of all the sulphides mentioned above, with the gangue minerals, proves that, except to a very limited extent, they are not later introductions, but that they are all contemporaneous in origin, and due to the same cause. No important additions of material from a deep-seated source were received after the completion of the contact metamorphism due to the igneous intrusions, for the later fractures and fissures are not mineralized, and contain only barren calcite and quartz. Yet these later fractures and fissures were important in the surface zone, in allowing a free circulation of atmospheric waters, which tended to concentrate the gold values in favourable localities. That this later arrangement of the values was due to surface waters moving downward is proved by the localization of the highest values on the igneous foot-wall, and the concentration of these values on the upper side of impervious dikes of later age which formed troughs or basins. (See Figure 3).

All of the known ore bodies are not widely separated from each other, but are segregated in the north central portion of the district, around the stocks and dikes of the diorite-gabbro complex. It has been shown that all these ore bodies are found on the contacts of the rocks of this complex with the sedimentary rocks. To restrict the occurrence further, it was stated that the best and most productive ore bodies occur on the gabbro contact, rather than on the diorite. To make further restrictions, it was seen that while massive limestones were readily altered by igneous intrusions, they were more favourable for the formation of copper deposits than of gold; the gold deposits, on the other hand, favoured the impure or thin-bedded limestones which were most easily altered by the intrusive rocks.

The primary ores of the district have no evident connexion with prominent fissures. The fissures that exist in the ore bodies are all of later formation, and contain little else than barren calcite or quartz. If fractures or fissures existed before the intrusion of the igneous rocks and the formation of the ore bodies—and it is very probable that they did—they have been completely obliterated by the recrystallization which took place in the contact zone at and immediately following the intrusion. The enriched ores, on the other hand, of the surface zone, have a direct connexion with fissures, and by affording channels of easy circulation to the surface waters, considerable enrichment has taken place in pockets or troughs, having more or less impervious boundaries. The depth to which this factor might be important has not yet been ascertained.

The ore bodies are generally tabular in shape, and dip at comparatively low angles. Although controlled to a considerable extent by the bedding of the sedimentary rocks, they are more certainly dependent on the dip and strike of the intrusive rocks with which they are associated. If the dip of the intrusive rock coincides with that of the sedimentary, then the ore body lies in the same stratum throughout. If, on the other hand, the dips of these two rocks do not coincide, then the dip of the ore body follows that of the intrusive rock.

It has been shown, also, that the boundaries of the ore bodies are not clean cut, but that the gold values gradually fade out into low grade rock. Neither are these values evenly distributed throughout the whole ore body, but the ore is rich in spots and lean in others. At the same time, gold is widely distributed throughout the contact zone formed by the gabbro intrusive, but it increases in a great many cases as the contact is reached. In most cases of the known ore bodies, the highest values are obtained directly on the gabbro contact, and on the upper side of the gabbro. In the Nickel Plate and Sunnyside No. 3 ore bodies a gabbro intrusive acts as the foot-wall. In these cases, also, part of the gabbro is mined as ore. A small assay value in gold can generally be obtained from the gabbro intrusives that are connected with the Nickel Plate and Sunnyside ore bodies.

From analysis of the different sulphides occurring in the ore bodies, it was found that while all have some gold, as well as silver, the highest values lie in the arsenopyrite. Analysis of pure arsenopyrite taken from the ore body gives a gold content varying from 0·30 of an ounce in gold up to 12·38 ounces per ton. In this, no gold whatever was visible under the microscope, and it was concluded that it must be either in a very finely divided state in the cleavage cracks of the arsenopyrite, or it was in actual solid solution in the arsenopyrite. In the former case, possibly, and in the latter case, certainly, its origin must have been contemporaneous with that of the arsenopyrite, and it was introduced at the same time.

While it is a rule that all workable deposits must contain arsenopyrite, and that the richest ore bodies contain more arsenopyrite than the poor, it is also certain that much arsenopyrite occurs throughout the district which will give little or no gold values on assay. Where, however, arsenopyrite occurs in the metamorphosed sedimentary rocks on a gabbro contact, it will always be found to contain some gold.

Finally, the gold values have been later concentrated by downward moving surface waters, not only on the foot-wall side of the ore body, but in impervious troughs that have been formed by the conjunction of a cross-cutting dike with the foot-wall. In certain cases, the highest grade of ore ever mined in the district has been recovered from such a trough, at a distance of 200 feet below the surface.

Theoretical Considerations.—In view of the evidence that has been brought forward with regard to the occurrence of the ore bodies, it seems clear that there is only one possible theory that will satisfactorily account for their formation. Other theories have been suggested during the progress of the work, and these also will be briefly discussed. Contact metamorphism, during which the primary ores were formed, accompanied by later secondary enrichment by downward moving meteoric waters, will, in the opinion of the writer, satisfactorily explain every known occurrence of workable ore bodies in the district.

The association of the ore bodies with the rocks of the diorite-gabbro formation, and particularly with the gabbro, is a proven fact, and to these intrusions it is believed that the ore is primarily due. All geologists agree in believing that contact metamorphism in rocks is due to the heat of the molten magma that has been forced into them. The great majority also believe that this metamorphism was aided to a very large extent by the action of water and other materials, which were given off by the molten magma and transferred to the intruded rocks. In these cases there was undoubtedly a transfer of material into the contact zone of the sedimentary rocks, for we find substances in that zone which are not native to the sedimentary rocks, and are not found elsewhere in them; and it is believed that all these substances were originally contained in the igneous magma. Among these various substances are iron, zinc, copper, arsenic, sulphur, and silica. Gold, also, is believed to have been present in the gabbro magma, for assays of the gabbro now generally reveal traces of gold. In places the gabbro carries so much that it is mined as ore, but these are always places where the gold has been introduced later, in the process of secondary enrichment.

This gabbro magma, which, as has been shown, must have been very hot, and was very fluid, carrying all the substances mentioned above in solution, forced its way upward through the overlying sedimentary rocks. As it reached higher levels, the pressure gradually diminished, and the dissolved substances, including gold, were released and passed off into the adjoining rocks, there to assist in the work of contact metamorphism, and to do the mineralizing. Those strata of limestone which are more thinly bedded, and afforded the easiest channels by their bedding planes for the emanations, were the most highly metamorphosed, and received the greatest addition of substance; while quartzites, argillites, and the more compact limestones, suffered less. In this way the primary ore deposits were formed at and near the immediate contact of the gabbro-intrusive.

That the ore deposits in this district are more generally associated with the dikes and apophyses than with the main stocks is a phenomenon which is not peculiar to these contact metamorphic deposits alone, but is common to other districts as well. The reason has only been partially explained. Lindgren,[1] in discussing the genesis of the copper deposits of Clifton-Morenci, says:

[1] Prof. Paper, U.S.G.S., No. 43, 1905, p. [illegible].

"These contact metamorphic deposits sometimes occur at the immediate contact of the main porphyry stocks and the limestones. But more commonly they seem to be connected with dikes of the same porphyry, close to the principal mass, these dikes being probably more highly charged with magmatic waters." The idea is a good one, and appears to be borne out in this district, for it is noticeable that even if economic deposits are not formed, the mineralization seems to be much more pronounced on the contact of the apophyses, than on the contact of the main stocks.

The depth at which the ore forming substances were released from the molten magma must have been considerable, so that the present outcrops were originally deep seated, and have only been exposed by a great deal of erosion. Garnet, epidote, diopside, and tremolite are the typical gangue minerals of these deposits, and in a recent classification by Lindgren[1] of minerals formed in ore deposits under varying conditions of depth, all of these minerals are classed as typical of the deeper vein zone, and below this. None of them are found in what he called the middle and upper vein zone, or the surface region. Their presence, therefore, in these bodies, shows that they were formed under conditions of considerable pressure, and much below the level of the surface as it then stood.

After the formation of the primary ore bodies by the intrusion of the gabbro, there was little, though some, later enrichment from the same magmatic source. Few fractures or fissures were formed by the cooling and contraction of the igneous rock, and of the contact zone; but those that did form were useful as channels for the introduction of some of the enriching sulphides. Subsequent to this, ore deposition from the same source was entirely at an end. Later, fractures were formed, but no new additions were received through them, from a deep-seated source. Not until these ore bodies, through erosion of the surface, came within the zone of influence of surface waters, was any change effected. Then the fissures, previously formed, permitted a free circulation of water, and the gold, leached out from its associated sulphides near the surface, was carried downward to enrich the ore body in favourable localities, below.

The above, in the opinion of the writer, is the most probable theory for the genesis of these ore deposits. Alternative theories

[1] W. Lindgren. The relation of Ore-deposition to Physical Conditions, p. 24.

have been suggested, but none seem to fit the conditions so well as the one outlined above. The theory of deposition wholly from solutions introduced through fissures from below is untenable. It has been shown that the fissures associated with the ore bodies are of a later period of formation, and if they have been used as channels for ore-bearing solutions ascending from below, some deposition of ore minerals must have taken place on their walls to give evidence of their having passed through them. These fissures are, however, not mineralized with primary sulphides, and contain only barren quartz or calcite. It is certain, however, that these fissures were useful in the surface zone to concentrate the gold values in low levels.

Another theory supposes the gold to be contemporaneous in origin with the sediments, and to have been deposited at the same time in the sea. In support of this is brought forward the fact that in certain beds gold values are widely and uniformly distributed through the sedimentary rock. The record of diamond drill holes Nos. 66 and 67 shows this to be true. But these are beds that are well within the sphere of influence of the gabbro intrusive, and it cannot be definitely proved that where these rocks are unaffected by igneous intrusions, the same results would be obtained. The fact also remains that no ore bodies have yet been found in unmetamorphosed rocks, nor in rocks that have not been metamorphosed by the rocks of the diorite-gabbro formation.

CONCLUSIONS AND CLASSIFICATION.

From the arguments presented in the preceding sections of this report, it is concluded that for the primary origin of the ores of the Hedley district, all agencies must be excluded, except those which are connected with the actual intrusion of molten magma into the sedimentary rocks, and that the ore bodies are of contact metamorphic origin. Contact metamorphic deposits have come in recent years to take a definite place in all genetic classifications of ore deposits, and the definition of W. H. Weed is one which is now generally accepted for deposits of this class. Weed says:[1] 'Under the title of contact metamorphic deposits I include all ore deposits which result from the metamorphic action of intrusive igneous rocks upon the sedimentary rocks which they penetrate. Such deposits occur only in the zones of altered sediments about igneous

[1] 'Ore Deposits near Igneous Contacts.' Trans. A.I.M.E., 1902.

intrusions; they are genetically connected with such intrusions, and are, therefore, fittingly designated as ore deposits of contact metamorphic origin."

The conclusion arrived at for the genesis of the Hedley deposits is one which had previously been accepted by those of the best mining geologists who had the opportunity of studying them. Mr. W. H. Weed was the first to make any published statement with regard to the origin of these deposits.[1] In this, he refers these deposits to the contact metamorphic group, but limits them to a distinct type which he calls the Similkameen type. This conclusion was arrived at apparently without having seen the deposits, and merely from information obtained from those who had. Since then, Mr. Weed has had the opportunity to examine them; and as no published statement has ever been made to contradict or modify his former opinion, it is inferred that he agrees with the original conclusions. Mr. W. Lindgren, whom it was the author's privilege to have look over a representative collection of the Hedley ores, concurred in the opinion previously formed that the deposits were of contact metahorphic origin. He, also, in a recent classification, limits the Hedley deposits to one of four types into which he divides the contact metamorphic deposits. This type he calls the arsenopyrite type, because it contains arsenopyrite as the principal ore mineral.

As a type of contact metamorphic deposits, the Hedley deposits are in a class by themselves, as far as North American ore deposits are concerned. A search through the literature of North American ore deposits reveals nothing of an exactly similar character, so that, as far as this country is concerned, they are unique. This fact has of contact metamorphic origin. He, also, in a recent classification, of ore deposits, and a separate division has been made to hold them. In Germany, however, at Reichenstein[2] a somewhat similar deposit, which contains arsenopyrite as the principal ore mineral, has been mined for a number of years. Here the ore occurs on a contact of serpentine with limestone. The serpentine is supposed to have been originally a feldspar augite rock, which, by its intrusion through the limestone, has effected the usual contact metamorphism with the development of arsenopyrite, as well as other sulphides in the contact

[1] "Ore Deposits Near Igneous Contacts." Trans. A. I. M. E., 1902.
[2] Stelzner-Bergeat, Die Erzlagerstatten.

zone. The arsenopyrite, as at Hedley, is gold-bearing, and the mines of Reichenstein, in the year 1904, mined 3,526 tons of ore, from which were extracted, by smelting, some 48 kilograms of gold. These mines were worked as long ago as the thirteenth century, and were very active during the sixteenth century. For many years, however, they remained idle, and operations were only resumed in 1850. The life of these mines, therefore, has been very long.

AGE OF THE ORE DEPOSITS

If we accept the theory of genesis propounded in the preceding section for the Hedley ores, we have no difficulty in assigning their formation to at least a relative age in the geological history of the district. Accepting their origin as due to the intrusion of the rocks of the diorite-gabbro formation, then their deposition took place at that time. The date of the intrusion of the diorite-gabbro cannot be definitely fixed, more than to say it is post-Carboniferous in age, since it is intrusive into Carboniferous sediments. It is believed that this intrusion took place immediately after the Carboniferous sediments were laid down, or early in Mesozoic times, and may have accompanied the uplift of these sediments. The primary ore deposition was effected at that time, and no new material has since been added from a deep seated source. Since then, erosion has been going on without interruption, and great thicknesses of the overlying rocks must have been worn away, and probably also much of the associated ore-bodies.

As the region has never been submerged beneath the sea since the close of the Carboniferous times, and its surface has been continually exposed to the action of atmospheric agencies since then, secondary processes, connected with oxidation and enrichment, must have been in operation for very long periods indeed. If the ore bodies ever extended upward in the sedimentary rocks beyond the present outcrop, at the beginning of the glacial period, there would have been a considerable accumulation of gold in the surface zone of these bodies. The great erosion accompanying the glacial period undoubtedly would carry much of this away. Since then the time elapsed has not been great, and oxidation has not been able to penetrate more than a few feet, so that the ore bodies are not as rich as they might have been. The present enrichment, however, might represent some of the pre-glacial enrichm[illegible] well as all that which has taken place since that period. The process has, no doubt, been a long continued one, and the intrusion of certain small andesitic dikes, through ore bodies that appear to have been already enriched, indicates a period of enrichment almost as far back as the granodiorite intrusion.

Mining, Milling, and Metallurgy.

The methods of mining employed in the Hedley district are not essentially different from those employed in other districts on ore bodies of a similar character, but somewhat different from those in use in fissure veins and like deposits. The earliest methods of mining, in nearly every instance, were by means of glory holes, but when these became too large, or so deep as to increase the cost of mining, tunnels or inclined shafts were driven and sunk, and the ore stoped out from either side by the overhand method. Timber is scarcely used at all, except in the tunnel entrances, and in broken or fractured parts of the mine. The rock is so strong that it will generally stand unsupported for a great width and considerable height; but for the safety of the miners, when the chambers become very wide pillars are left for the support of the roof. In the Nickel Plate mine the roof is firm and strong, and no danger is ever experienced from falling blocks. In Sunnyside No. 2, however, where the gangue of the ore is largely calcite, some care has to be exercised, particularly in the spring, when much water is seeping through the walls and roof from the melting snows on the surface. Accidents, however, from falling blocks are rare.

A favourite method of stoping employed in the Nickel Plate mine is to break down a lot of ore, commencing on the foot-wall and working upward, and using the broken down ore as a floor on which the miners work. In this way, a great deal of ore is broken down, and lies in the shoots ready to be drawn off. A quantity of about 300 tons or so is kept on hand.

In the Nickel Plate mine cars driven by electricity enter the working tunnel, and are loaded directly at the shoots, or from the face of the drift. Two ton cars are used, and from here a train of ten cars is hauled by an electric motor to the ore bin at the head of the gravity train. Compressed air is also used at the heads of inclines as an auxiliary power, and this is supplied either from a steam or water-power compressor. The latter is situated at the

Gravity tram line, lower section.

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bottom of the Similkamen valley, 4,000 feet below the tunnel mouth. From the Sunnyside workings, trains of twelve 2 ton cars carry the ore to the bin, where they are dumped mechanically by an ingenious contrivance, the invention of Mr. G. P. Jones, superintendent of these mines.

All ore mined goes to the mill, and there is virtually no waste, except the drift, which is scraped off the surface of the ore bodies by scrapers. No sorting whatever is done either at mine or mill, but by a judicious mixing of the different grades of ore, the average value per ton is kept at a fairly constant figure, and much low grade ore is mined thereby which would be unprofitable if mined alone.

Exploration in former years has not been kept much in advance of actual mining, and the mines have been leading a hand to mouth existence. Within the last two years, however, there has been a change for the better, and a great deal of exploration has been done, by means of the diamond drill, and by open-cuts.

Accurate data with regard to the cost of mining are not available. Some of the ore is so hard that the cost of drilling is not always the same, and frequently runs high. The lack of the necessity for timber in the mines, and the glory hole method, make mining cheaper now than it will be when greater depth is attained. The use of water-power to generate electricity, and to run the air compressor, reduces costs somewhat, and the advantage of using vity alone to transport the ore part of the way from mine to s also economical. Altogether it is safe to say that mining ransportation will not cost more than $2 per ton, and $1.75 would probably be nearer the actual figure.

Up to the present time, the ores of the district have been subjected to three different methods of reduction, namely, amalgamation, cyanidation, and smelting. The two first named of these operations are carried on in the district by the Daly Reduction Co., while smelting of the concentrates recovered after amalgamation is done at a smelter at Everett, Washington, U.S.A. This smelter is the only one in the west which at present will accept arsenical ores.

All the ore extracted from the mines of the district is treated by the Daly Reduction Co. in a 40 stamp mill and cyanide plant, which is situated at the bottom of the Similkameen valley, 4,000 feet below the mines. Connexion between the mines and mill is effected partly by means of electric tramway, and partly by gravity tract. The electric tram-line is over one mile in length, and trains of 10 or 12 two ton cars transfer the ore from the mine to a large bin at the head of the gravity tram-line. The gravity tram-line is about 10,000 feet in length, and has to overcome a difference in elevation of about 3,000 feet. The grade of this is such that transportation can be effected entirely by gravity, though in the upper half compressed air is used in addition to gravity. The track is three-railed, except at the central passing stations, and is built almost entirely on the ground. It follows the slope of the mountain, so that the grade varies all the way from 10 per cent up to 66.8 per cent. The cars are 5 ton skips, attached to a heavy 42 strand wire cable, which passes over a head gear at the top. The loaded car going down pulls the empty car up. The gravity tramline is divided into three sections, on account of slight bends in the line, and it is operated from end to end by four men. They handle 150 tons of ore in 10 hours, but this amount could be largely increased, if necessary.

The stamp mill at the base of the mountain is also built on the slope, so that ore entering the bins at the top of the mill will travel from one stage of treatment to another by gravity alone. The whole plant is very substantially built, its foundations resting on the solid granite, and at the time of its completion, 5 years ago was complete and up to date in every respect. From time to time, slight changes have been made to keep up with the more recent advances in mill practice, and to meet the various changes that have taken place in the character of the ore. Power for the different units is supplied by water, which is brought in a 4 ft. x 5 ft. flume from nearly 3 miles up Twentymile creek.

From the gravity tramway the ore is delivered to a bin at the top of the mill. After passing over grizzlies, it goes through two Farrell type jaw crushers of 10 inches x 20 inches and 6 inches x 20 inches openings respectively. These discharge to a belt conveyer, which distributes the ore along the entire length of a 1,000 ton storage bin, and from this it passes through automatic feeders to the eight batters of five stamps each. The stamps weigh 1,050 pounds each, and they drop about 100 times a minute, into Homestake mortars weighing about 8,000 pounds each, and set in cement on the solid granite. The amalgamating plates under each battery of stamps are 16 feet long and 54 inches wide, arranged in pairs. Only the upper

PLATE XX.

Stamp mill and cyanide plant of the Daly Reduction Co.

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one of each pair is now used, as the character of the ore milled has rendered the lower plates almost useless.

On the battery floor, also, there are three separate water wheels. A 36 inch wheel supplies power for the crusher and belt conveyers, a 72 inch Pelton is connected with the cam-shaft, and a 24 inch wheel drives the vanners on the floor below.

From the amalgamating plates, the pulp is classified and goes to Frue vanners. These are 24 in number, 16 being provided with smooth belts, and receiving the fine product of the classifiers, and 8 having corrugated belts, which treat the coarse product. The concentrates recovered from these, which consist very largely of arsenopyrite, are sacked and stored, and later shipped to the smelter at Everett, Washington, U.S.A.

The tailings from the vanners are again classified to sands and slimes, and the whole product is treated in the various portions of the cyanide plant. This consists of solution, slime, and settling tanks, with strong gold and sump tanks, filled and discharged either by gravity or by centrifugal pumps. The final tailings are then sluiced into the creek.

The strong gold solution afterwards passes to the zinc boxes, where the gold is precipitated from solution. The precipitate is afterwards treated with sulphuric acid, and then washed and dried, after which the product goes to the furnace and is reduced, and the bullion cast into bars.

Near the stamp mill is also a power plant for generating electricity and compressed air for the mines. It is run by water, a head of 414 feet being obtained from the penstock at the head of the flume, which furnishes a pressure of 190 pounds to the square inch. A 16 ft. Pelton wheel drives a Rand compound air-compressor, and a smaller 24 inch Cassel wheel, of 100 horse-power, is connected to an electric generator. The Rand compressor furnishes compressed air for the hoists and drills at the mines, through a 6 inch pipe line 18,000 feet in length. The pressure delivered at the mines, after an elevation of about 4,000 feet, is about 100 pounds to the square inch. The electric generator furnishes power for the mine tramway, and light for the town and mine buildings. During the winter months, when water is scarce, power is generated by a 140 horse-power Ball steam engine, which also heats the mill.

Carpenter, blacksmith, and repair shops are also part of the equipment. A telephone system connects all parts of the mine, tramways, and mill with the main office and with each other.

Under the present management, a number of improvements have been made in the mill practice. The duty of each stamp has been considerably increased, and is now about 3·35 tons per 24 hours. The quantity milled daily at this rate amounts to about 135 tons. As the ore is an auriferous arsenopyrite, gold is virtually the only product, and an extraction of about 92 per cent of the total value of the ore is made from amalgamation, cyanidation, and smelting. A small percentage of copper, silver, and some platinum is known to occur in the ores, and essays show a variable proportion of cobalt, nickel, lead, and bismuth. The arsenic is a waste product so far as the mines are concerned, and no credit is given for it by the smelter.

Since the inception of the processes of reduction of the ores in the spring of 1904, a total of 153,003 tons have been treated. All of this amount has been derived from either the Nickel Plate or Sunnyside mines, and treated by the Daly Reduction Company's plant. Below is a tabulated statement of the number of tons of ore mined and treated annually:—

	Nickel Plate.	Sunnyside.	Total.
	Tons.	Tons.	Tons.
1904			9,000
1905	17,437	14,994	32,431
1906			35,000
1907			31,576
1908			45,006
			153,013

General Status and Future Possibilities.

The Hedley district stands at present in the position of a mining camp with a great many undeveloped and even unprospected mineral claims, and only two producing mines. The great majority of these claims are surveyed and Crown granted, so that no annual assessment work is necessary for the owners of these to hold them. The result is that all this ground is tied up, and little is being done to demonstrate to the outside world the potentialities of the district.

or even the possibilities of new ore bodies being discovered. Some, however, of these owners, in spite of great difficulties and many discouragements, have preserved their faith in their claims, and continue to do each year some work over and above that demanded by law, with the result that the value of their claims is enhanced, and prospective buyers are more easily enabled to form an opinion as to their real worth. In justice to many other owners of claims in the district, it must be said that to a man of limited means the difficulties to be overcome, and the uncertainty of knowing where to do their prospecting, have been great, and it is no wonder that many have become discouraged.

In the early stages of mining in this district, less than ten years ago, the future looked bright, and much prospecting was carried on in and around the Hedley district. As time went on, however, and promises of cheaper transportation by railway connexion with outside points were not realized, the hopes of many fell, their enthusiasm waned, and some left the district altogether for other places where conditions looked to them more favourable. Less and less work was done each year, and when a Crown grant was obtained, it meant in many cases the cessation of work altogether.

To add to the disadvantage under which the district laboured from lack of transportation, was the difficulty of knowing where to look for ore. To the average prospector the occurrence of ore of this type is strange, and even in the case of a great many mining engineers it takes a thorough study of the geological conditions before they are able to do intelligent prospecting and development work. There were no well-defined leads to follow, and no quartz veins. Free gold was rarely to be seen, and good workable ore looked not unlike mineralized country rock, which contained little that was of economic importance. For a long time operators in this district were working in the dark, and even at the present time the best they can do is to follow closely what ore they have in sight, and none are bold enough to run long tunnels, or sink shafts in barren ground, with the idea of striking ore at a certain expected point. It was some time before the contact metamorphic origin of the ore was recognized, and the uncertainty and irregularity that are generally connected with ore bodies of that character had only to be ascertained by much prospecting in which there was a great deal of useless work. Again, the ore is of such a character that, as a rule, one can tell very little about its value from an examination of a sample by the eye alone. Chemical analyses are the only means of acquiring that knowledge, and the expense of continually having assays made soon becomes too great a burden for the prospector of limited means.

The drawbacks, therefore, to successful prospecting in this district have been exceptionally great; and when it is contended that after about ten years of life the district has only produced two working mines, because there are no others to be found, the above disadvantages must be borne in mind. To offset these, and to give some aid to the prospector, the work of the Geological Survey was instituted, and already the work has borne fruit. It is hoped that further benefit may be derived from the work when the results obtained become more generally known.

At the present time the industrial activity of the district depends almost entirely on the operation of the Nickel Plate and Sunnyside mines, by the Yale Mining Company, and of the Daly Reduction Company's stamp mill. These two Companies employ altogether about 110 men when in full working order. The mines, as well as the mill, are in operation on an average about 10 months in the year, and they are only forced to close down during the remaining two months by a lack of water for power for the mill. If the water supply was constant or greater, there is no reason why, with proper conservation and protection of the water they have against frost, the mill could not be kept in operation constantly, and mining be carried on at the same time. The district, however, is a semi-arid one, and the scarcity of water at all times of the year is a problem which future operators in the district will have to face. On the two mines, active work has been carried on by the Yale Mining Company for the last ten years, and at the present time their annual output is about 36,000 tons of ore. All of this is treated by the Daly Reduction Company, whose mill has now been working about five years.

No other claims in the district have so far produced any gold, and few have had much work done on them. The Kingston Mining Company, owning a group of claims on the Twentymile slope of the Nickel Plate mountain, has been the most active, and though working somewhat intermittently for several years, has done much to prove the value of the claims.

Although it is difficult in the Hedley district to get away from the action of mineralization, there are no outcrops known—other than those on the two working mines—which suggest a richness approaching that of the bonanza ores of the Nickel Plate mine already worked. These ores were not only very rich on the surface, but the high values persisted to a depth of about 200 feet vertically from the surface, or nearly 300 feet along the pitch. These ores, which were mixed with a poorer quality of ore to preserve a constant grade, have been the mainstay of the district since the period when extraction of gold began. An unknown quantity of this yet remains, but all of the ores must suffer some lessening of grade, as the upper enriched zone is mined out.

The search for the outcrop of an ore body of similar value to the Nickel Plate ore body has been in progress ever since the camp was first discovered, but apart from the ore bodies on the Sunnyside mine, no others have yet been found. Whether any exist is still the problem. If our theory of the genesis of the ore bodies be true, these ore bodies are located in the most favourable portion of the whole district, for here the necessary geological conditions of igneous intrusion are accompanied by the proper topographic conditions for the concentration of ores, that is to say, the dip of the sedimentary strata, and of the gabbro intrusions, bears such a relation to the slope of the ground that continued oxidation and erosion of the surface would always be conducive to enrichment. Where such conditions could be exactly duplicated, there would be a chance for similar kinds of ore bodies. As the sedimentary strata of the dist. all have dips toward the west, eastward facing slopes are more likely to produce strong surface enrichment than those which slope in the other direction. Where gabbro intrusives occur under these conditions, enriched ore bodies have been found, and should recur again. On westward facing slopes, enriched ore bodies are likely to occur only under peculiar conditions, and the normal unenriched ore would be more in evidence.

With such surface enrichments, however, the future of the district is not so greatly concerned as it is with those ores below the surface zone, which have not been concentrated by surface agencies. Sooner or later, all surface ores must be worked out, and the lower grade ores of the deeper zone developed. These must be the ores on which the future of the district will depend.

Up to the present, little has been done to demonstrate the extent or value of these primary ores, but this has been due largely to the isolation of the district, and the necessity of having fairly high grade ores, or ores of at least $10 to the ton, to repay the cost of mining and treatment.

It is certain that much ore of a low grade remains untouched on the Nickel Plate mine, and is not now mined on account of the high cost of mining and reduction. With improved methods of mining, change of treatment, or cheaper transportation, much of this could be utilized profitably, and undoubtedly will be, at some future date. All prospecting in the district, for reasons already given, is expensive; but a systematic search for ores of a grade about $8 or $9 to the ton, should reveal some ore bodies, especially in the circle of which Climax bluff forms the centre, and within a radius of one mile. No such systematic search has yet been attempted, except in restricted areas, so that our knowledge of the distribution and occurrence of the ores is far from complete. The outlining of the Nickel Plate formation, in which the Sunnyside and Nickel Plate ore bodies occur, should aid this search considerably, and every contact of gabbro intrusives with the calcareous members of this formation should be closely studied. When this is done some new ore bodies should be discovered.

Though the chemical characteristics of the Nickel Plate formation are duplicated in portions of two of the other formations of the district, the situation of these formations with relation to the gabbro rocks is not so favourable, and it is probably only this reason that might militate against the formation of ores in them. If well exposed rocks make prospecting easy, then the Hedley district is not difficult, but is well favoured. Diamond drilling could be carried out with good effect in the search for new ore bodies, and in fact has been used very extensively by the Yale Mining Co. Owing to the ill-defined nature of the ore bodies, the effectiveness of diamond drilling is not as great as it might be in districts where the leads are better defined and more regular, but this method undoubtedly gives better results for the same outlay than any other kind of prospecting. The idea of driving long tunnels in barren rock, with the hope of striking ore bodies at expected points, or of discovering new ones, has nothing to recommend it in a district carrying ore bodies of this character.

The values in unenriched ores, where they are known, run so near to the present actual cost of extraction, that other factors, such as situation, character of rock, and mining facilities, would determine the economic value of any such deposit as may be discovered. The slopes of the district, particularly in the valley of Twentymile creek, are such that all mining development could be carried on by means of tunnels instead of the more expensive shafts.

A problem which future operators in the district will probably be called upon to face, is a change in the character of the ores, necessitating a change in treatment. From the experience of the Daly Reduction Co., in their stamp mill, it appears very likely that smelting of the ores will eventually replace the processes of amalgamation and cyanidation now in use. It has been found that as depth was attained in the mines, the ore extracted yielded less and less of its gold content on the amalgamating plates, and a larger percentage went into the concentrates, from which it has to be extracted by smelting in a blast furnace. There is no doubt, also, that some of the ores of the district now known to carry pay values cannot be treated at all in the stamp mill, and all of these will have to go to a smelter. Thus the possibility of all of the ores of the Hedley district being eventually reduced in blast furnaces is not remote. Whether this will be done by the erection of smelters on the ground, or whether the ores will merely be concentrated and shipped elsewhere, will depend on whether suitable fuel can be obtained, and cheap power developed.

The Princeton coal basin, which covers at least 50 square miles, is distant only about 25 miles, and contains many seams of easily worked coal. The coal, however, is lignitic, and has not been proved to be capable of producing a firm coherent coke suitable for smelting. A coal basin of yet unknown extent, but probably much smaller than the Princeton area, lies to the south and west of the mouth of Granite creek, about 40 miles west of Hedley. It has not yet been shown whether this coal will coke or not, but the grade is better than a lignite, and it may furnish a commercial coke. A very fair grade of bituminous coal, of the same age as the Princeton and Granite Creek coal, is being worked in the Nicola valley, and this is distant by wagon road from Hedley about 100 miles. Altogether this district is very favourably situated for fuel, and need never lack a cheap and constant supply, when railway connexions are made. At present, none of this coal is used at Hedley, either for domestic purposes or for the generation of power.

Water-power obtained from Twentymile creek is the only power now utilized, and this operates the reduction works and haulage, as well as supplying electricity to the town and mines. The horse-power that can be generated from this source is, however, limited, and is not even now equal to the demand. A further supply cannot, therefore, be expected from this source. There is said to be a possibility of developing water-power on the Ashnola river, about 12 or 14 miles distant in a southerly direction, and also on the Similkameen river above Princeton. A company has been formed at Hedley with the object of using the water of the Similkameen river at this point for power purposes; and very possibly something could be done, but the writer is not competent to offer an opinion on such a scheme. It is certain, however, that when the demand for power arises, some scheme will be devised to meet it, provided the demand is great enough.

DETAILED DESCRIPTION OF THE MINES AND PROSPECTS

NICKEL PLATE MINE.

Location.—The Nickel Plate mine is the best known mine in the Similkameen district, and, like the Sunnyside, is owned by the Yale Mining Company. It was staked in the summer of 1898, by Wallaston and Arundell, and sold by them to M. K. Rodgers, in 1899. Rodgers was then representing the late Marcus Daly, and acquired the claims in his name, afterwards forming the Yale Mining Company to operate them. The mine is situated on the eastern slope of Nickel Plate mountain about 200 feet below the summit. The outcrop of the ore body lies at an elevation of about 5,900 feet above sea-level, or 4,300 feet above the town of Hedley. On this outcrop a large glory hole has been opened up, but the main adit tunnel is 150 feet below. The slope on which the mine is situated is not steep, and runs down to one of the branches of Eighteenmile creek. It was formerly heavily wooded with spruce, but is now almost bare, except for a second growth of young pine springing up.

Geology.—The Nickel Plate mine lies wholly in the rocks of the Nickel Plate formation. These rocks consist in this part of the formation of massive blue limestone below, passing upward into more impure siliceous limestones, with which are interbanded some thin beds of fine-grained cherty quartzites. These dip at angles from 20° to 30° to the west, directly into the mountain. Numerous sheets and dikes of the white gabbro, locally known as andesite, emanating from stocks of this rock lying on the western slope of the mountain a short distance away, have been intruded into these sedimentary rocks. The majority of these gabbro intrusives are in the form of sheets, and follow the bedding planes of the sedimentary rocks. Some, however, cut across the bedding planes. Besides the gabbro intrusives, there are dikes of various kinds. The most common are hard black dikes of lamprophyre, which have no uniform strike. Some soft dark green andesite dikes are also present, and one or two keratophyre dikes, locally referred to as quartz porphyry.

The gabbro intrusives, in penetrating the sedimentary rocks, have effected intense contact metamorphism, so that the carbonates of the original rocks have been completely transformed to silicates. This alteration has been greatest in the higher impure limestones, while the massive blue and white limestones below have suffered less. The minerals now found in the highly altered rocks are garnet, epidote, diopside, amphibole, wollastonite, and some axinite, and with these are the sulphides, arsenopyrite, chalcopyrite, pyrrhotite, and some blende and pyrite.

Character of the Deposit.—The ores of the Nickel Plate, like all the others in the district, are of the contact metamorphic type, and are situated on the contact of a gabbro intrusive with the altered limestones. The gangue is made up of the lime silicates, principally reddish garnet and green epidote, with subordinate diopside, amphibole, and calcite. The ore minerals are arsenopyrite, and some chalcopyrite, pyrrhotite, blende, and pyrite. Some tetradymite occurs at and near the surface. These ore minerals are distributed through the gangue, either in well crystallized individuals, or as filling minute fractures. The values are entirely in gold, which appears to be associated, as a rule, with the arsenopyrite. In the ores near the surface considerable gold was visible, but in the present workings, at 150 to 300 feet below the surface, no gold is visible either with the naked eye or the microscope.

The limits of the ore body that is being mined have been very closely defined by the officials of the Yale Mining Company by diamond drilling, but in an ore body of this character it is hard to give a satisfactory idea of its dimensions, when its boundaries are not well marked. In shape, the ore body is tabular, dipping at an angle of 25° to the west. Its most clearly defined boundary is on the lower or foot-wall side. Here it rests directly on a sheet of gabbro. At right angles to this foot-wall the ore gradually fades out into low grade rock, so that its boundary on this side is a question of the cost of mining and treatment. Its lateral boundary on the south and west is a curving keratophyre dike, locally known as quartz porphyry. On the east the ore body outcrops at the surface, and on the north it has no definite boundary, and is very irregular in outline.

Taking the boundaries of the ore body as outlined above, it is found that it had originally a greatest length of about 600 feet, as far as known, and a greatest width of about 150 feet. The thickness from the foot-wall to the top of the pay ore was variable. The greatest thickness mined was about 55 feet, but the average is less than half that. The strike of the longer axis is about N 55° W and the dip about 25° to the westward. The greater part of this particular ore body has been already mined out, and it is not known to extend much farther downward.

The ore body does not here follow any one bed of the sedimentary rocks for the whole of its 600 feet, but like the gabbro foot-wall, which cuts diagonally across the bedding planes, it passes from one bed to another in going downward. It does not appear to be closely connected with any system of fissures or fractures, though a well-marked and strong fracture cuts across the ore body just at its outcrop, and is now seen in the glory hole. This strikes almost north and south. The ore body, at a depth of about 200 feet, is cut also by a small black dyke, which strikes in approximately the same direction as the fracture. This dike is evidently later than the formation of the ore body, and having the same trend as the large fracture, suggests that the fracture also is later than the formation of the ore body.

The gold values are by no means evenly or regularly distributed through the ore body, but they are far more uniform here than in most of the other ore bodies in the district. There is a strong tendency to have the highest values concentrated on the foot-wall, and to die off gradually at right angles to this. At the same time, where the gabbro foot-wall came in contact with the cross-cutting keratophyre dike and the black dike, forming a sort of V-shaped trough, there was found to be a remarkable concentration of the ore values, and some of the richest ore in the mine was taken out at this point.

Below the ore body that is now being mined, and underneath the gabbro foot-wall, there is known to be another ore body, but of a grade that cannot now be mined profitably. This also rests on a gabbro foot-wall, but its character, values, and dimensions have not been determined.

General Development.—The Nickel Plate ore body was first mined as a large glory hole. [illegible] resent the main entrance to the underground workings is by me[illegible] of No. 3 tunnel. [illegible] runs into the hill-side for a distance of 717 feet, entering the ore body at a point 520 feet from the portal. This point is 150 feet lower than the outcrop of the ore body at the glory hole. Drifts have been run on either side on this level, and on an intermediate level between this and the glory hole. From this level, also, an incline goes down to the northwest on the pitch of the ore body. The ore is stoped out, leaving large chambers, and the roof is supported by pillars of the ore. No timber whatever is used except for a few feet near the portal of the tunnel.

At a point about 150 feet below No. 3 tunnel, and to the northeast of it, No. 4 tunnel runs into the hill for a distance of 1,163 feet. This was run with the purpose of cutting the ore body at greater depth, and of making this the main adit tunnel, but the ore body was not found at the expected point, and the tunnel has never been used for the purpose intended.

No. 3 tunnel is lighted by electricity, and rails are laid so that the ore trains run right in and load from the ore shoots. Electric power is used on these trains, but compressed air on the incline and for the drills and pumps.

SUNNYSIDE MINE.

Location.—The Sunnyside mine adjoins the Nickel Plate on the south, and like the latter, is owned and operated by the Yale Mining Company. It was staked in August, 1898, and with the Nickel Plate, Bulldog, and Copperfield mineral claims, was sold the following year to M. K. Rodgers. It consists of four separate workings.

which are all located from 250 to 300 feet below the outcrop of the Nickel Plate glory hole, and on either side of the 5,600 ft. contour line. These workings are on the eastern slope of the Nickel Plate mountain, and lie on the line of the electric tramway, which is part of the haulage system connecting the mine with the reduction works at Hedley. The four workings are located on separate ore bodies, and are referred to as Sunnyside No. 1, Sunnyside No. 2, Sunnyside No. 3, and Sunnyside No. 4.

Geology.—The country rocks of the Sunnyside mine belong to the Nickel Plate formation, but are of a lower horizon than those of the Nickel Plate mine. They belong to the portion of the Nickel Plate formation directly above the massive blue Sunnyside limestone, and consist of bands of blue and white limestone—the latter crystalline—with some siliceous limestones and bands of chert. These dip to the westward at angles from 10° to 25°, and show besides some gentle folds with axes running in the same direction (west). The rocks are traversed by several systems of fractures, varying in strike from due west to N 25° E. The most pronounced of these have a bearing of N 85° W and of N 6° W. Gabbro intrusives have everywhere been thrust through the sedimentary rocks in the form of sheets, dikes, and irregular bodies. Besides these, both the country rocks and the ore bodies are cut by small black lamprophyre dikes and dark greenish andesite dikes.

In their intrusion through the limestones, the gabbro bodies have effected the usual contact metamorphism by alteration of the limestone to diopside, garnet, epidote, amphibole, and quartz. This alteration is naturally greatest in the immediate contact of the gabbro, while a few feet away the limestone has merely become crystalline. This is exemplified in the case of Sunnyside No. 3, where the foot-wall is a gabbro intrusive, and the ore body is made up of the sulphides in a gangue of epidote and diopside; while in Sunnyside No. 4, and also in No. 2, there has been less alteration and the original carbonates still remain. Besides the above-mentioned minerals, the contact zone also contains disseminated crystals of arsenopyrite, pyrrhotite, chalcopyrite, blende, and pyrite.

Character of the Deposits.—Like the Nickel Plate ore bodies, the ore bodies of the Sunnyside are of the contact metamorphic type and are situated in the zone of contact metamorphism caused by the intrusion of the gabbro bodies.

The immediate relation of the ore body on Sunnyside No. 1, to the gabbro, is not apparent in the workings. These workings, however, are of limited extent, and what ore body is known is situated in limestones, which have been somewhat silicified by presumably contact action. Directly above it and only a few feet away, however, is a large sheet of gabbro, which effects strong mineralization on its contact with the limestones. The extent and character of this ore body is not well known, and little has been done on it.

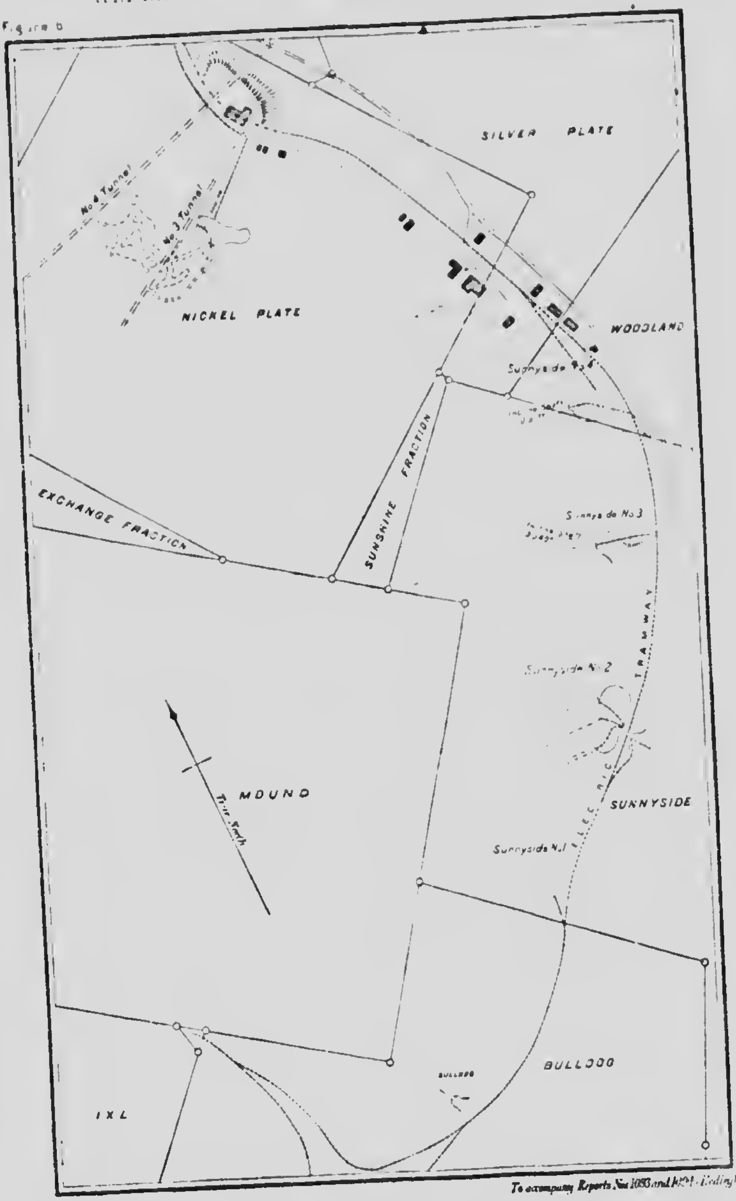
Sunnyside No. 2 has so far proved to be the largest of the ore bodies on the Sunnyside mine, and the one which has yielded the greatest amount of ore. It lies entirely in the altered limestones, and is tabular in form and conforms to the bedding of the sedimentary rocks. It dips about 10° to the west, and has a width, as far as is now known, of about 170 feet, and a length of about 220 feet, so that it is roughly oval in shape. The foot-wall is a bed of white crystalline limestone, and on the hanging-wall the ore fades out into low grade rock, at a distance of from 10 to 20 feet from the foot-wall. On the lower or western side the boundary is sharply defined by a dark green andesite dike, which strikes north and south. On the eastern side it outcrops at the surface, where a gabbro dike is also exposed. On the other sides—the north and south—it gradually fades away into ore too low grade to work. The gangue of the ore is composed of the lime silicate minerals—diopside, garnet, amphibole, and epidote—but these are not so abundantly developed as in the Nickel Plate mine, and a great deal of calcite yet remains. These minerals occur often in well-defined bands which conform to the original bedding planes of the rock. The ore minerals are arsenopyrite, pyrrhotite, chalcopyrite, and blende, occurring disseminated through the gangue, or in well-defined bands. The blende, particularly, appears in bands a few inches wide, which are parallel to the bedding planes of the sedimentary rocks. The values are entirely in gold, and are more concentrated in the lower portion of the ore body, near the foot-wall, than in the upper. A strong zone of fracturing runs through the ore body from east to west, and there appears to have been some displacement and faulting along this line, with the upthrow on the south side. About 35 feet above the foot-wall, and exposed in the glory hole, is a sheet of gabbro, but the upper limit of the ore body never reaches to this, except perhaps in the glory hole on the surface.

On Sunnyside No. 3, the conditions are very similar to those on the Nickel Plate. In this case a gabbro intrusive has been thrust into the limestones, effecting strong contact metamorphism, and the ore body rests directly on the gabbro which acts as the foot-wall. The gabbro dips at an angle of 40° to the west, while the dip of the altered limestones is 25° in the same direction. The ore body outcropped on the surface, and has been mined to a depth of 120 feet on the dip. A width of about 25 feet of ore has been mined, and about the same thickness measured at right angles to the foot-wall. The gangue of the ore is composed largely of diopside, with a lesser amount of garnet, epidote, and calcite. The sulphides are arsenopyrite and pyrrhotite, occurring either in well-defined crystals or in bunches. The values, as in all other cases, are not uniformly distributed through the gangue, but are spotted, with, however, a tendency to concentration on the foot-wall. In this case the only well-defined boundary is the foot-wall, and on all sides there is a gradual transition into low grade ore.

On Sunnyside No. 4, the geological relations have not yet been definitely worked out. Here the ore lies in a stratum of limestone not much altered, and about 8 feet thick. The limestone is simply crystalline, and shows no tendency to develop the lime silicates. Certain beds, however, associated with the ore stratum, show evidence of metamorphism, in the development of large crystals of quartz, which are embedded in the limestone. The only igneous rocks apparently immediately connected with the ore body are black lamprophyre dikes which cut it. The strata are either horizontal, or dip about 10° to the west. A fracture zone, in which no pay ore occurs, cuts off the ore body to the west, but it has been proved by diamond drill to be present again on the other side of the fracture zone. The ore consists of disseminated crystals of arsenopyrite, and bunches of pyrrhotite, in a gangue of crystal calcite.

General Development.—The main line of the electric tramway runs directly in front of the entrances to each of the workings. Sunnyside No. 1 has the least amount of work, and has been developed by means of short tunnels aggregating about 200 feet in distance. Sunnyside No. 2 was first worked as a large glory hole, immediately adjoining the main tramway. The area of this glory hole is about 200 feet in length, 75 feet in width, and from 10 to 35 feet in height. The underground workings have three main

Figure 6



PLAN OF THE YALE MINING COMPANY'S MINES

(Reduced from Company's Plans)

Scale

Feet ... Feet

entrances, into each of which rails are laid and the ore cars enter. The south tunnel runs in about 140 feet from the edge of the glory hole to the face. The middle or main entrance is on an incline of 10°, and runs in toward the west 189 feet. Drifts run off from this to the north, and large chambers are mined out, the roofs of which are supported by pillars of ore. The greater part of the known ore has already been extracted from this ore body.

On Sunnyside No. 3, an incline of 120 feet runs down on the dip of the ore, and the cars are drawn up by a donkey engine on the surface. These cars dump into an ore bin situated on the main tramway.

Sunnyside No. 4 was also originally mined as a glory hole, but recently a tunnel has been driven in from the main tramway for a distance of about 240 feet on the ore stratum. The last 60 feet of this is on an incline of 17°.

Besides the development on their shipping mines the Yale Mining Company, during the summer months of the years 1907 and 1908, have kept two diamond drills steadily at work in prospecting their claims for other ore bodies. The cost of this work has been in the neighbourhood of $70,000. At the same time an enormous amount of surface work has been done. Their claims are riddled with pits and open-cuts, and nearly every outcrop has been carefully sampled.

Production.—Taking the Nickel plate and the Sunnyside mines together, the total production has been given on a previous page as the total production of the whole camp. From 1904 to the close of 1908, the number of tons mined and treated in the mill has been 153,000. The value per ton of this has varied somewhat, and has perhaps decreased, but its average has been in the neighbourhood of $15. The extraction from this has been about $1 less than the total assay value.

THE KINGSTON GROUP.

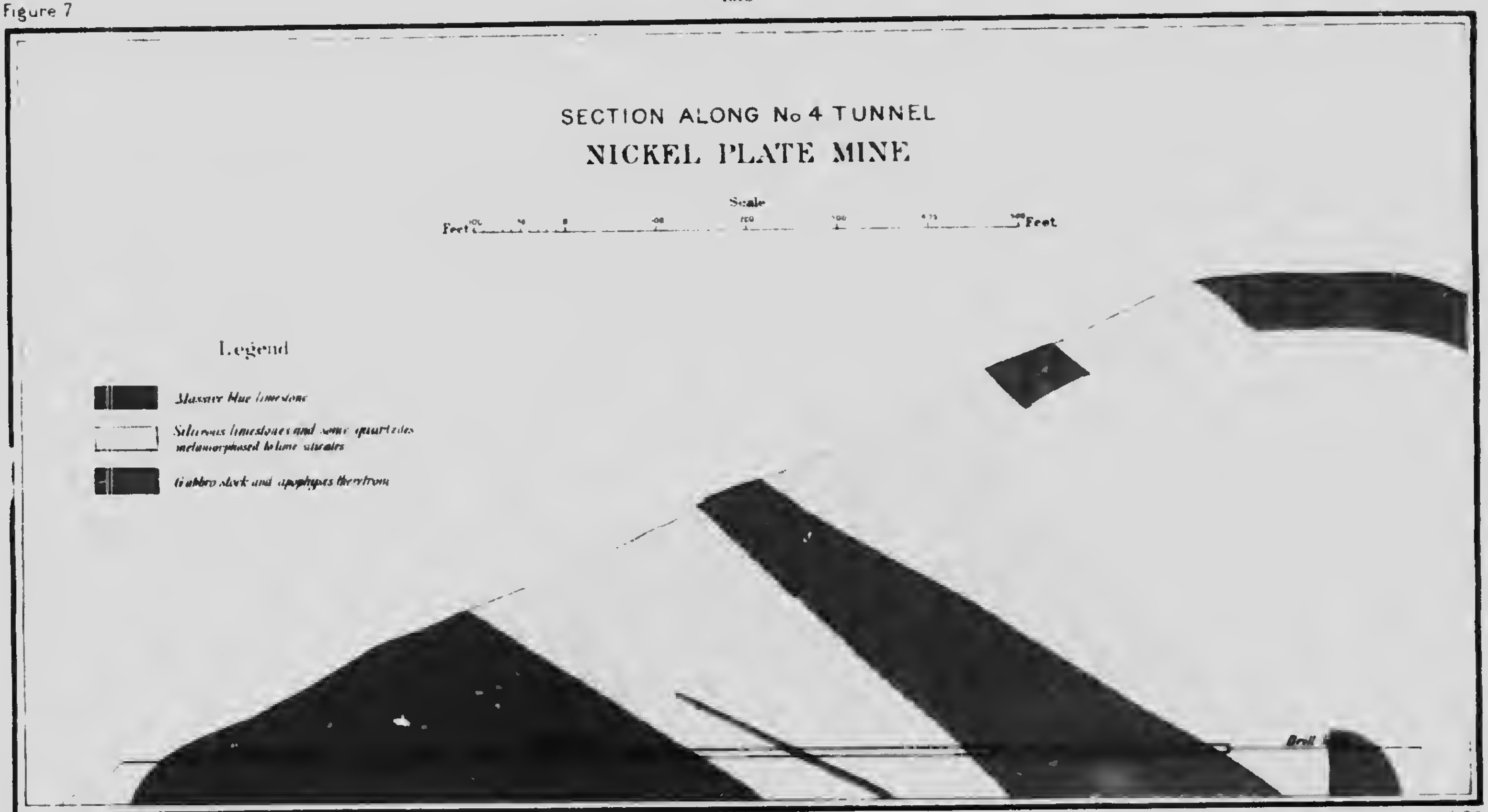
Location.—The Kingston group comprises five claims, namely, the Metropolitan, Kingston, Kingston fraction, King, and Warhorse mineral claims. These are located on the western slope of Nickel Plate mountain, running down to Twentymile creek, and on either side of the Horsefly gulch. The lower portion of the group lies at an elevation of 3,100 feet, or 1,400 feet above Twentymile creek;

Canada
Department of Mines
GEOLOGICAL SURVEY

Hon. W. Templeman, Minister; A. P. Low, Deputy Minister
R. W. Brock, Director

1910

Figure 7



1129

To accompany Memoir No 2

while the upper boundary of the group is about 2,800 feet above the creek. The group is owned by the Kingston Mining Company, which has done more prospecting and development work than any other company or individual in the camp, with the exception of the Yale Mining Company.

Geology.—The sedimentary rocks of the Kingston group belong to the upper portion of the Nickel Plate formation, and consist of limestone beds, with which are interstratified some quartzite bands and thin reddish tuffs. All of these beds, however, have been so highly altered by intrusions of igneous rocks as to consist now of the lime silicates, garnet, epidote, diopside, and amphibole. They have a general dip to the southwest of from 15° to 35°, except in the case of an isolated triangular area on the Metropolitan, where the dip cannot be definitely determined, but appears to be to the southeast.

The sedimentary rocks are cut off on the north by a body of quartz diorite, which runs directly up the mountain side to the east. The quartz diorite also sends off many apophyses into the sedimentary rocks, both as dikes and sheets. Some gabbro dikes are also present, as well as many diorite porphyries. To the southeast of the group, a large dike of granodiorite, 500 feet wide, separates the sedimentary rocks from the main body of the Nickel Plate formation, and extends southward to the Similkameen river.

As all the ores of the district are found only in the sedimentary rocks, and so far, only in those of the Nickel Plate formation, the area of sedimentary rocks on each group of claims is important. On this group there are two distinct areas separated from each other by a tongue of diorite running down to the southwest from the main body. The smaller of these sedimentary areas lies on the Metropolitan claim, and is triangular in shape, with each side of the triangle from 800 to 1,000 feet in length. It is surrounded on two sides by diorite, and on the third by granodiorite. The whole area is very highly metamorphosed, and cut with dikes of porphyritic diorite and gabbro. From the regularity of its strike, it is to be expected that the contact of granodiorite and the sediments will be an almost vertical one. On the other hand, judging by the nature of its intrusion, and the great amount of contact metamorphism, it is likely that the diorite contact will be a plunging one, and it may be found to dip underneath the sediments so as to eventually cut them out altogether in depth.

The larger area of sedimentary rocks lies above the smaller, and to the southeast of it. It, also, is bounded on the southwest by ... an diorite, and on the north by diorite, and is in the form of a V ... h ... d body, widening to the southeast, as it goes up the side of the ... ntain. This, also, is cut by a great many sheets and dikes ... vritic diorite and gabbro, as well as some smaller dikes of ... nd lamprophyre, which are intrusive both into the sedi... ' into the granodiorite and diorite masses.

... r of the D posits.—The ore d ... osits ... the Kingston ... be divided into two groups—those containing copper as ... al ... able metal, and those containing gold. On each ... velopment work has been done, but no ore ... up to date.

... eposits have been exposed by workings principally ... the V ... claim. They lie in what were originally limestone ... as at ... he contact of the rocks of the diorite-gabbro complex, which have altered the limestone to the familiar rock composed of garnet, epidote, diopside, and amphibole. The limestones are interbedded with some siliceous bands, and they dip at an angle of about 30° to the west. The gangue of the ores is the lime silicate minerals, and the ore minerals themselves are chalcopyrite, pyrrhotite, arsenopyrite, and galena. These are scattered through the gangue in varying proportions, with pyrrhotite usually in greatest proportion. The chief values that have been obtained are in copper, but this is supplemented by some values in gold and silver. The highest values in silver obtained in the whole camp are got from this ore, which frequently gives 8 to 10 ounces to the ton. An average sample of the ore on the dump of the Warhorse will give about 6 per cent of copper. The extent of the ore body on the Warhorse has not been defined, but the development work has shown the outcrop of an ore body, of considerable economic importance.

A similar occurrence of copper ore is known on the Kingston mineral claim, 800 feet below the Warhorse, but here again, the extent of the ore body has not been defined.

Gold ores in payable quantities occur on the Kingston and Metropolitan mineral claims, under similar conditions to the copper ores. While each of these occurrences is of contact metamorphic origin, and is found in the zone of contact metamorphism induced by the intrusion of the diorite, the area and general outlines of the ore bodies have not been definitely determined. Most of the work has been done on the Kingston claim. Here, gold values from $5 to $20 have been obtained in considerable quantity on the surface, in the sedimentary rocks, within 100 feet of the contact of the diorite. In one of the most likely places, the outcrop of a payable ore body has been found in the sedimentary rocks alongside a black lamprophyre dike which strikes north and south across the side of the hill. This ore body has been explored by a shaft 11 feet deep, and found to be payable to the bottom, but a tunnel run in to cut this ore body, at a depth of about 50 feet, failed to show any pay ore at that depth, perhaps because the ore body dips at a low angle to the southwest, and passes over the tunnel. Surface cuts in the same neighbourhood show ore occurring in payable quantities, but it remains to be proved where these ores go to, and whether they are payable at greater depths.

On the Metropolitan mineral claim, which covers the triangular area of sedimentary rocks already referred to, some very good results and high values have been obtained by recent work. The gold ores here are also of contact metamorphic origin, and are associated with the gabbro and diorite intrusives, within 200 feet of the main contact of diorite. The sedimentary rocks are here very highly altered indeed, and are made up of reddish and greenish garnet, epidote, and diopside. No well-defined bedding planes can be made out, but the rock is frequently sheared and traversed by fissures and faults. Surface ores on this claim give assays as high as $100 to the ton, and oxidation does not extend downward more than a few inches. In fact, most of the outcrops are quite unaffected by oxidation. At a depth of about 50 feet from the surface an ore body, with a greatest width of 14 feet, was discovered, dipping at a low angle to the southeast. This lies in the metamorphosed sedimentary rocks on either side of a highly altered zone of rock, 1 to 3 feet wide, which appears to be a dike of rhyolite. The ore minerals are principally arsenopyrite, and some chalcopyrite, occurring in a gangue of lime silicates, and much free gold can be seen. The gold is in small thin flakes apparently following minute fracture planes, and is clearly of a secondary nature, that is, the result of percolating gold-bearing solutions of probably meteoric origin. The values are by no means evenly distributed, but are, on the contrary, very erratic, so that assays give variable results. Results as high as $200 to the ton have been obtained in portions of the workings. While the gold is generally found in small fracture planes, some of the zones of fracturing are quite barren, indicating that this fracturing is of later date than the ore formation.

The ore body has no definite walls, so that its exploration is difficult. The extent of this ore body has not yet been determined, but work is still in progress, and it is hoped that the results will be highly satisfactory.

General Development.—More exploratory work has been done on the Kingston group than on any other group, with the exception of the Yale Mining Company's properties. Work has been in progress for nearly ten years, and considerably over $50,000 has been expended. This work has been confined to the Warhorse, Kingston, and Metropolitan mineral claims. On the Warhorse some 200 feet of tunnelling and much surface work has been done. On the Kingston there are two main tunnels. The upper one runs in 80 feet to the east, with drifts of 60 feet on either side to the north and south. The lower tunnel runs in about 110 feet, with a drift of 30 feet to the north. Besides this, shallow prospect shafts have been sunk, and much stripping of the surface has been done. On the Metropolitan, a shaft has been sunk 58 feet, with drifts at the bottom, to the north and south, of 20 feet each. Below the shaft, 120 feet of drifts and tunnels have been run. On the surface, also, much stripping of the rock has been done. No ore has yet been shipped.

FLORENCE GROUP.

The Florence group of claims consists of the Florence, Whale, Bullon Beek, Florence fraction, Little Pittsburg, Zerust and Eagles' Nest, seven claims in all, situated in the northern part of the district, and on either side of Bradshaw cañon. They lie on the eastern side of Twentymile creek, and in the angle formed by the bend in the valley of that stream. The lower limit of the group reaches almost to Twentymile creek, while the upper limit is on the top of the Aberdeen ridge, at an elevation of 5,500 feet above sea-level.

The group covers, on the eastern side of Bradshaw cañon, some rocks of the Red Mountain formation, and on the western side a larger area of the Aberdeen formation. Through the centre and southern portions of the group runs a broad strip of the Nickel

Plate formation, which widens toward the base of the cañon, and connects with the main body of these rocks on Nickel Plate mountain.

The strongest and most marked fault in the district runs directly through this group of claims, and down the Bradshaw cañon. An earlier fault to the west of the cañon has displaced the rocks of the Nickel Plate formation, so that they are first upthrown on the western side, causing them to reach the summit of the mountain. Then the Bradshaw fault has downthrown them on the same side, so as to bring the Red Mountain formation almost to the foot of the cañon, with the Nickel Plate formation hidden beneath it altogether.

Dikes of diorite and mica diorite have invaded the older rocks in several places and sheets of gabbro have also been thrust into them. Besides these intrusive rocks, there are smaller dikes of andesite, and of the so-called quartz porphyry, which cut all the above-mentioned rocks.

The development work has been largely by tunnels and much surface work, and some good values have been obtained in connexion with the gabbro sheets.

HUMMING BIRD GROUP.

The Humming Bird group, owned by J. J. Marks and some others, consists of eight claims situated in the northeast corner of the district, and to the west of Lookout mountain. The surface rocks of the group are entirely those of the Red Mountain formation, overlying at some depth the Nickel Plate formation. They dip at moderate angles to the west, and are intruded by dikes of diorite and some gabbro.

Considerable development has been done on the group by surface cuts, shafts, and tunnels. Four diamond drill holes were also sunk, aggregating almost 2,000 feet, but no information was available as to the results obtained.

Other prospects in the camp on which a certain amount of development work has been done are the Windfall group, lying in the Windfall cañon, the Fairy Queen group at Central station, and certain claims owned by Geo. Cahill and Duncan Woods.

APPENDIX.

Certain mining districts tributary to the Hedley district, but not included in country covered by the geological map, were cursorily examined during the course of the work. These districts are the Golden Zone camp, locally known as the Quartz camp, and the Henry Creek district, each of which is worthy of mention as having had considerable work done in it, and of having been the cause of some local excitement.

THE GOLDEN ZONE CAMP.

Location.—The camp was located in the year 1900 by Messrs. Murphy, Brodhegan, and Marks, and consists at present of four surveyed and Crown granted mineral claims. These claims are the Silver Bell, Golden Zone, B.C., and Irish Boy. The camp lies at an elevation of about 5,900 feet above sea-level, and is situated on the head waters of Twentymile creek between its east and north forks. A wagon road 11 miles in length connects it with Hedley, and was completed in 1908. This wagon road also connects with Penticton, which is distant about 30 miles. The country here is thickly wooded, but the original timber has been burnt off and is replaced by a second growth of young pine. Exposures of rock are not numerous, but there is a thin mantle of drift over all.

Geology.—The oldest rocks are of sedimentary origin, and are probably of Carboniferous age, similar to the Hedley sediments. No fossils, however, have been found in them. They consist of limestones, quartzites, and tuffs, all of which have been considerably metamorphosed by later igneous intrusions. They dip at an angle of 30° to the southwest. These contain interbedded sheets of diorite, and some gabbro, showing a strong similarity to the rocks of the Hedley district.

Intrusive into these sedimentary rocks, and found only on the two western claims, is a body of fine-grained micaceous granite. This weathers very readily, so that a fresh sample is difficult to obtain. It consists of feldspar, quartz, and hornblende, and much biotite. It has undergone some metamorphism, probably from orogenic disturbances, so that a gneissic structure is frequently developed in it. On its contact with the sediments it becomes finer in grain, and more acid in composition.

Lying to the south of the fine-grained granite, and the sediments, is a coarse-grained pinkish granite of apparently batholithic proportions. This appears to be later in age than the fine grained granite, for though the actual contact was not found exposed, it appears to hold inclusions of the fine-grained granite, and to send off apophyses into it. It consists of large crystals of pink and white feldspar, quartz, mica, and some black hornblende, all so highly developed as to indicate crystallization under conditions of considerable time and pressure.

Intrusive into all of the above rocks, and lying in the south-eastern part of the district, is a body of granite porphyry of dike like proportions. This has an average width of about 1,000 feet, and lies between the coarse-grained granite and the sedimentary rocks, and in direct contact with each. Into each of those rocks it sends off apophyses. Its constituents in the centre of the mass are phenocrysts of quartz, feldspar, and biotite, in a fine-grained acid ground-mass. The composition remains unchanged southward, to the granite contact; but on the north, on approaching the sediments it undergoes a change. Here it becomes more acid, the biotite disappears, and the only phenocrysts are glassy quartz, which are embedded in a pinkish feldspathic ground-mass. The metamorphic action on the sediments has been to change them to a dense grey siliceous rock, in which some mineralization has taken place, as shown by crystals of arsenopyrite. No such mineralization is apparent on the granite contacts with this rock. Some shearing, and the formation of small fractures has taken place in the granite porphyry.

Character of the Deposit.—The claims have been staked on a well-defined and persistent quartz vein, which can be traced in an east and west direction for over 1,200 feet. This vein cuts both the fine-grained granite and the sediments. In the former, it occupies a strong fissure, varying in width from 2 to 4 feet, but on passing into the sediments it appears to split up into four or five smaller veins.

The lead is a true fissure and frequently shows a well marked ribbon structure, due probably to the filling of an open space. The walls are clean and smooth, and often show slickensiding. The dip of the vein is about 90°.

The gangue is a hard white quartz, and the ore minerals occurring in this are pyrite, arsenopyrite, blende, and chalcopyrite. On the surface the quartz is generally honey-combed, on account of the weathering out of the sulphides. Below the zone of oxidation, it is seen that the sulphides appear in well crystallized individuals in the gangue, as well as filling minute fractures of a later date than the crystallized individuals. The sulphides filling the fracture planes are, as a rule, arsenopyrite and pyrite.

The age of the quartz veins is rather problematical, but they are probably later than the intrusion of the quartz prophyry, and may be genetically connected with it as an after effect. Undoubtedly orogenic movements have taken place both before and after the formation of the quartz vein, for the vein is slightly displaced by a fracture to the west, so recent that it still preserves its topographic expression.

The values are in gold as well as some silver, and are said to be higher in the sedimentary rocks than in the granite. On panning some of the decomposed ore on the surface, a number of very fine colours of gold are obtained among the arsenopyrite concentrates in the bottom of the pan. No samples were taken for assay, though the results obtained by the owners and others are said to be very satisfactory indeed.

General Development.—The property is equipped with a five stamp mill, which was hauled in on sleighs and installed in 1908. No serious milling has yet been attempted, however, on account of the failure of the water supply.

The development work consists of a shaft sunk to a depth of 115 feet on the vein near the mill. A second shaft, 250 feet to the west, is down 47 feet on the vein. Besides these, several small pits have been sunk at intervals on the vein, at a distance of 1,000 feet from the main shaft. Numerous open-cuts and trenches have also been made across the veins, especially in the neighbourhood of the contact of the sedimentary rocks with the fine-grained granite.

THE HENRY CREEK DISTRICT.

Location.—Henry creek is a small stream entering the Similkameen river from the south about two miles above the town of Hedley. A group of five claims now owned by the Pollock Mines Company was first staked on this creek in 1900. These are now surveyed and Crown granted, and are called the Martin, Daisy, Maple Leaf, Minnehaha, and Pine Knot. They lie on both sides of Henry creek. The lower boundary of the group is at an elevation of 400 feet above the Similkameen river, and the upper limit is 2,000 feet above that stream. Access to the workings, which are 900 feet above the river, is by means of a pack trail. The grade of the Great Northern railway crosses the mouth of Henry creek 300 feet below the lower boundary of the group.

Geology.—The country rock of the district consists of black limestones and argillites, and some volcanic tuffs and breccias interbedded together in thin beds not more than 1 foot in thickness. They belong to a somewhat higher horizon than the rocks of the Hedley district, but are apparently conformable with them. They have been subjected to strong orogenic movements, and now dip at very high angles, and strike about north and south. Fissures have been developed in these rocks in a north and south direction, in a most marked degree, while in directions transverse to this they are traversed by numerous minute fractures.

An irregular body of diorite, apparently identical with the Hedley diorite, is intrusive into the sedimentary rocks. This passes through the claims in an east and west direction, attaining its greatest development in the centre of the group, where it has a width of about 1,400 feet. The contact with the sedimentary rocks is very irregular, and apophyses of the diorite project out into the sedimentary rocks, cutting across the strike of the beds.

Both the diorite and the sedimentary rocks are cut by soft greenish dikes of an andesitic character, which strike north and south about parallel to the strike of the sedimentary rocks. Other dikes somewhat similar in appearance, but of a more siliceous nature, also cut the sedimentary rocks, and probably also the diorite.

Character of the Deposits.—The deposits of the Henry Creek district are fissure veins lying in the sedimentary rocks in the neighbourhood of the diorite contact. The sedimentary rocks are everywhere traversed by minute fractures which contain some pyrite and arsenopyrite, and which have no definite trend. The fissures, however, on which the work has been done, are strong and well-defined, and have in general a north and south strike.

The main workings of the group lie at an elevation of 900 feet above the Similkameen river, and are located on a well-defined fissure, which has been traced for at least 500 feet. The width of this is not constant, but varies from 2 feet up to 12 or 14 feet, with an average of about 5 feet. The gangue which contains the ore minerals is both quartz and calcite, and these cement together fragments of the country rock with which the fissure is full. The ore minerals are largely arsenopyrite with some pyrite, which are found in the quartz and calcite, as well as in the small fracture planes in the country rock. The values here are chiefly in gold, and in the decomposed outcrop of the vein free gold was easily obtained by panning.

The upper workings of this group lie at an elevation of 1,400 feet above the Similkameen river. These also are located on quartz veins, which, however, cut the diorite as well as the sedimentary rocks. The most persistent of these veins has been traced on the surface for a distance of 500 feet in a north and south direction, and it has a dip of about 45° to the west. Another vein lies almost flat, but is only a few inches wide. The gangue is a white quartz, which carries as ore minerals, arsenopyrite, pyrite, and some galena. The values here are also chiefly in gold, with some silver. In places they were found to be high, but were not uniform. The best results were obtained in the lower workings.

General Development.—Considerable work has been done on this group of claims at different times, but this has now been discontinued. On the upper quartz veins, the work consists largely of a series of open-cut and shallow pits. A tunnel, also, has been run in on the flat lying lead for a distance of over 100 feet.

On the lower workings, there are two inclined shafts at the north end near the diorite contact. One dips 60° to the west, and is down 60 feet, with a cross-cut at the bottom of 30 feet; the other dips 50° to the west, and is down 55 feet. There are also five tunnels running westward into the side of the mountain. The longest of these is 148 feet in length, and at the time of examination had two drifts along the vein to the north and south, the one 30 feet in length, and the other 64 feet. Another tunnel above the longer one is 60 feet in length. Besides these there are three shorter tunnels, all cutting the main lead at different points.

INDEX

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Can
Department
GEOLOGICA

HON. W TEMPLEMAN MINISTER
R W BROCK,

AREAL GEOLOGY

LEGEND

PALAEOZOIC MESOZOIC

Hedley diorite

Sediments and tuffs
limestones and argillites with interbedded black tuffs considered to be of Carboniferous age;

Symbols

Geological boundary

C. O. Senécal *Geographer and Chief Draughtsman*
O. E. Prud'homme *Draughtsman*

MAP

MINERAL CLAIMS

Near HEDL

Henry Creek about 2 miles west of Hedley B.C.

Scale

Feet

100 0 100 500

Metre

100 0 100 200

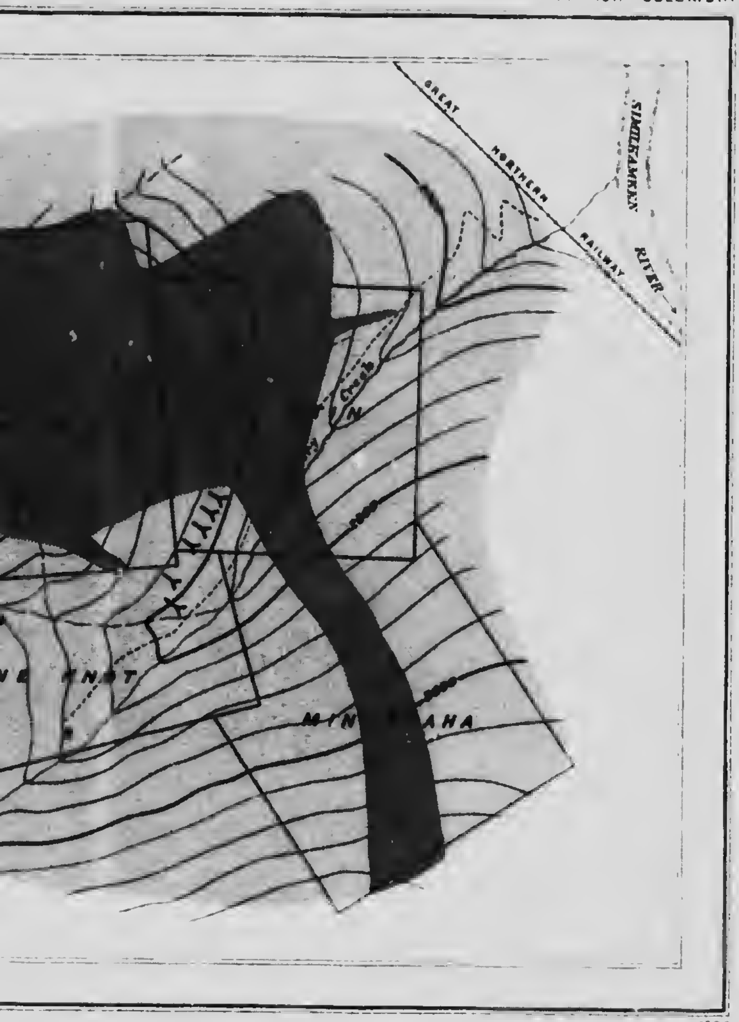
800 FEET

Canada
[De]partment of Mines
[G]EOLOGICAL SURVEY

[...]n Minister A P Low, Deputy Minister
R W Brock, Director

1910

BRITISH COLUMBIA



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LEGEND

Culture

Railways

Trails

Tunnels

Prospects

Water

Rivers and creeks

Intermittent streams

Relief

Contours
(Showing land forms and elevations above sea level) Interval 100 feet

MAP 3A

[CL]AIMS on HENRY CREEK

[N]ear HEDLEY B. C.

Scale: $\frac{1}{9600}$

Feet: 1000 1500 2000

Metres: 100 200 300 400 500

[8]00 FEET TO 1 INCH

GEOLOGY
Subject to revision
C. CAMSELL 1908

TOPOGRAPHY
C. CAMSELL 1908
L. REINECKE 1908

To accompany Memoir No. 2

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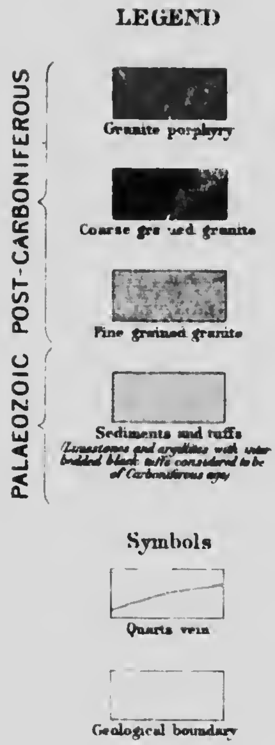
R W Bro



ECONOMIC GEOLOGY

C.O.Senécal, *Geographer and Chief Draughtsman.*
O.E.Prud'homme, *Draughtsman.*

Situation about 8 miles north of Hedley B.C.

GOLDEN ZON

Near H

Sc

100 0 500

100 0 100

600 FE

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Department of Mines
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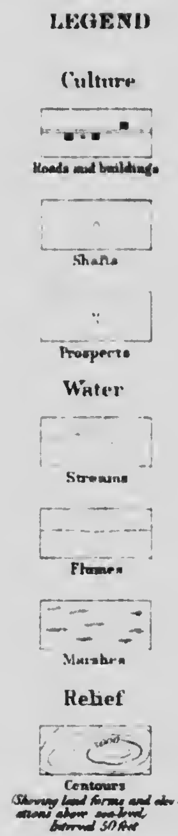
...LEMAN MINISTER   A.P. LOW DEPUTY MINISTER.
R. W. BROCK   DIRECTOR

1910

BRITISH COLUMBIA



MAP 4A

...N ZONE MINING CAMP

Near HEDLEY B.C.

Scale

Feet
1000   1500   2000
Metres
100   200   300   400   500

600 FEET TO 1 INCH

GEOLOGY
(Subject to revision)
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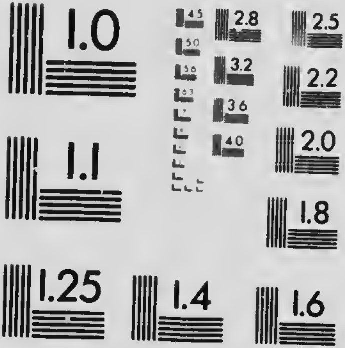
(Subject to revision)
C. CAMSELL   1908

To accompany Memoir No 2

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



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HON W. TEMPLEMAN, MINIST
R.W. BROC

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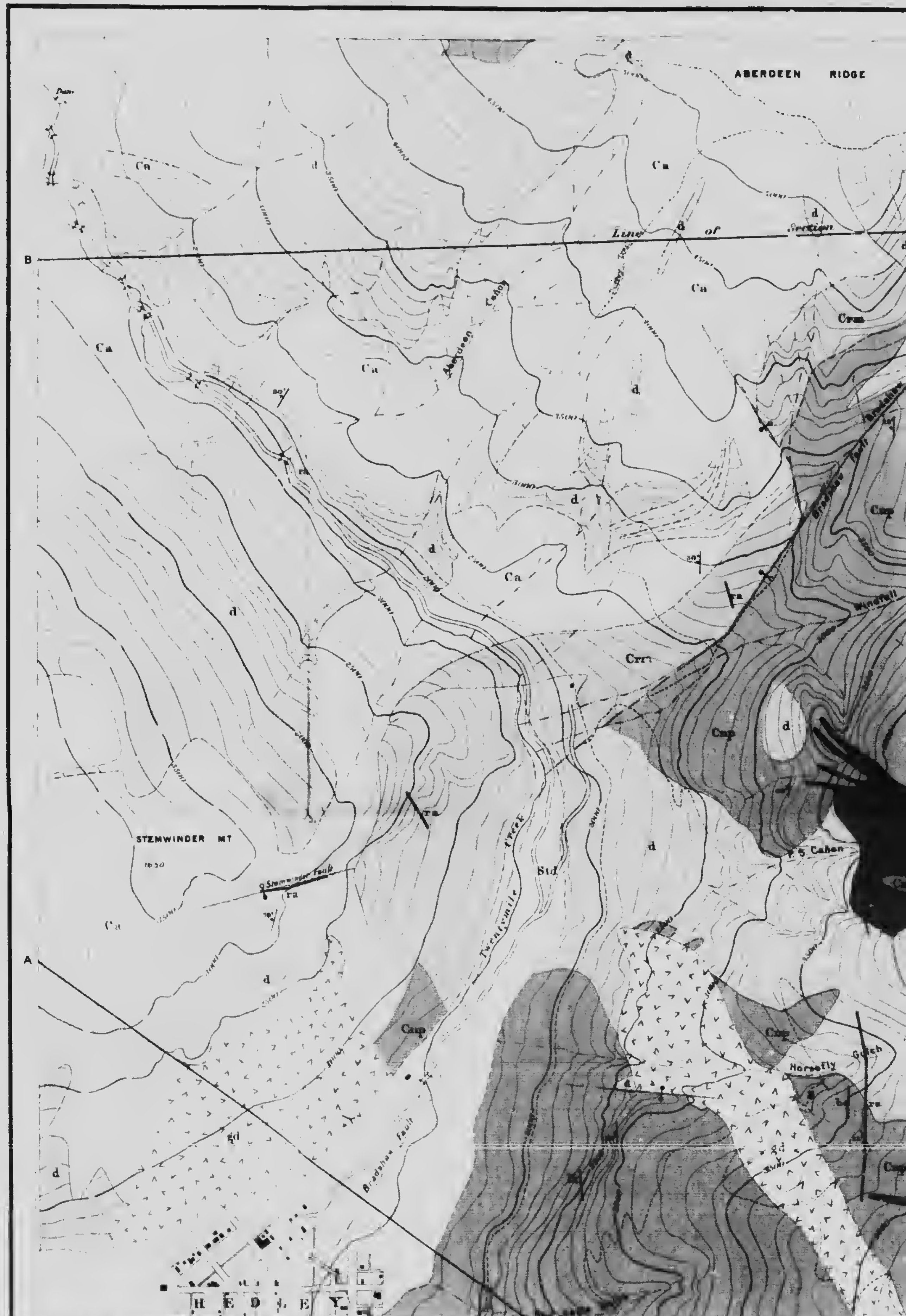


LEGEND

Sedimentary rocks

QUATERNARY — RECENT

Std
Superficial deposits
stream gravels and sands

PALAEOZOIC — CARBONIFEROUS

Ca
Aberdeen formation
thin bedded limestones quartzites and argillites, some tuffs and volcanic breccias

Crm
Red Mountain formation
tuffs and volcanic breccias with some interbedded quartzites and argillites

Cnp
Nickel Plate formation
limestones and quartzites with thin bands of argillite and tuff

Crt
Redtop formation
limestones quartzites argillites tuffs and breccias

Igneous rocks

TERTIARY

ra
Dike
aplite, rhyolite and andesite

gd
Granodiorite

MESOZOIC

lk
Dike
lamprophyre and keratophyre

Gabbro
porphyritic in places and having a marginal facies of diorite

d
Diorite
diorite quartz diorite mica diorite and porphyritic diorite

Symbols

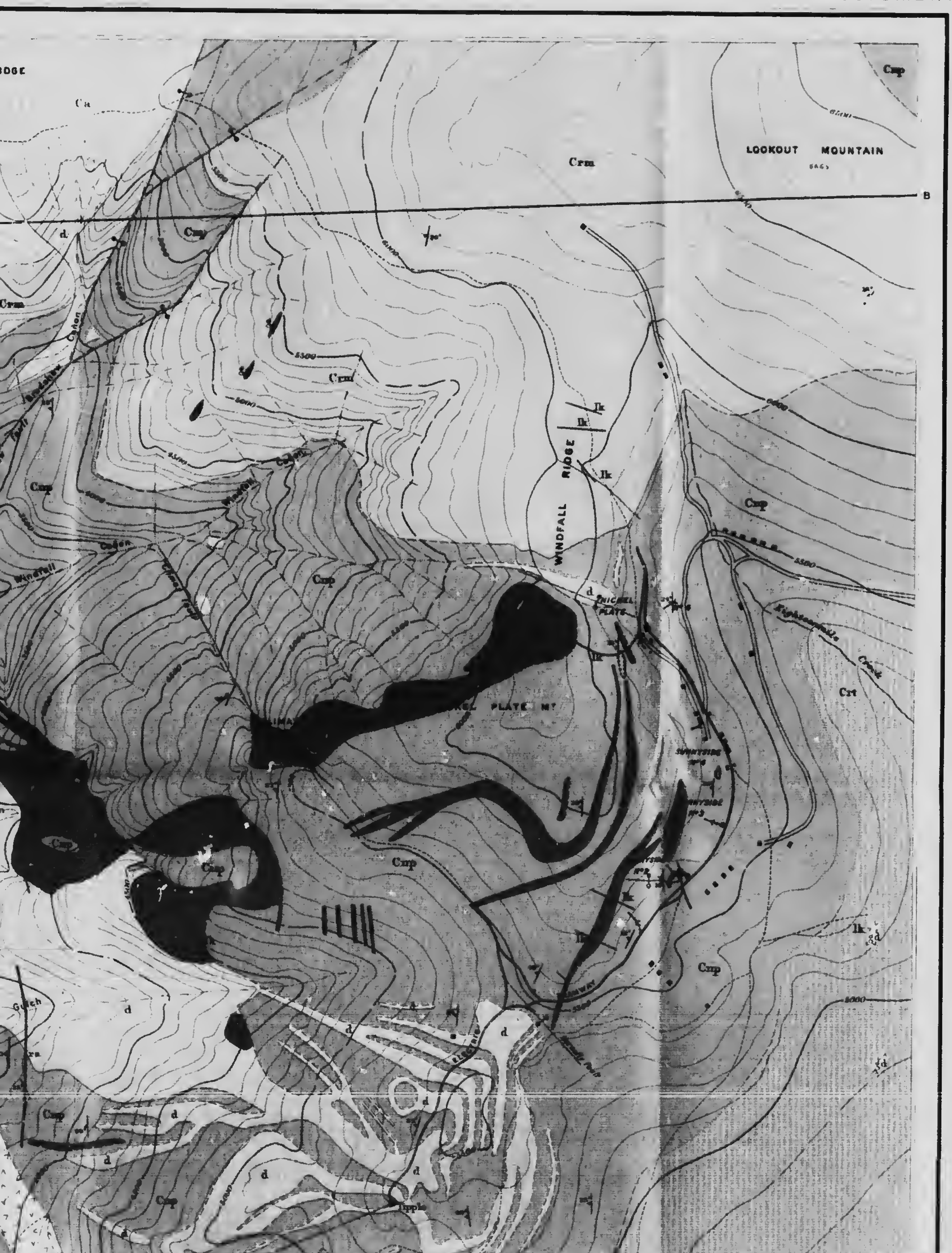
Fault

Canada
artment of Mines
EOLOGICAL SURVEY

AN, MINISTER, A.P LOW, DEPUTY MINISTER;
R.W. BROCK DIRECTOR.

1910

BRITISH COLUMBIA



LEGEND

Culture

Roads and buildings

Trails

Railways

Tramways

Electric tramways

Bridges

Tunnels

Mine tunnels

Dams

Mine excavations

Water

Rivers and streams

MESOZOIC

Gabbro
porphyritic in places and has a marginal facies of diorite

d

Diorite
[illegible] quartz diorite [illegible] and porphyritic [illegible]

Symbols

Fault

Fault
inferred but not seen

Fault
downthrow side

Fault
upthrow side

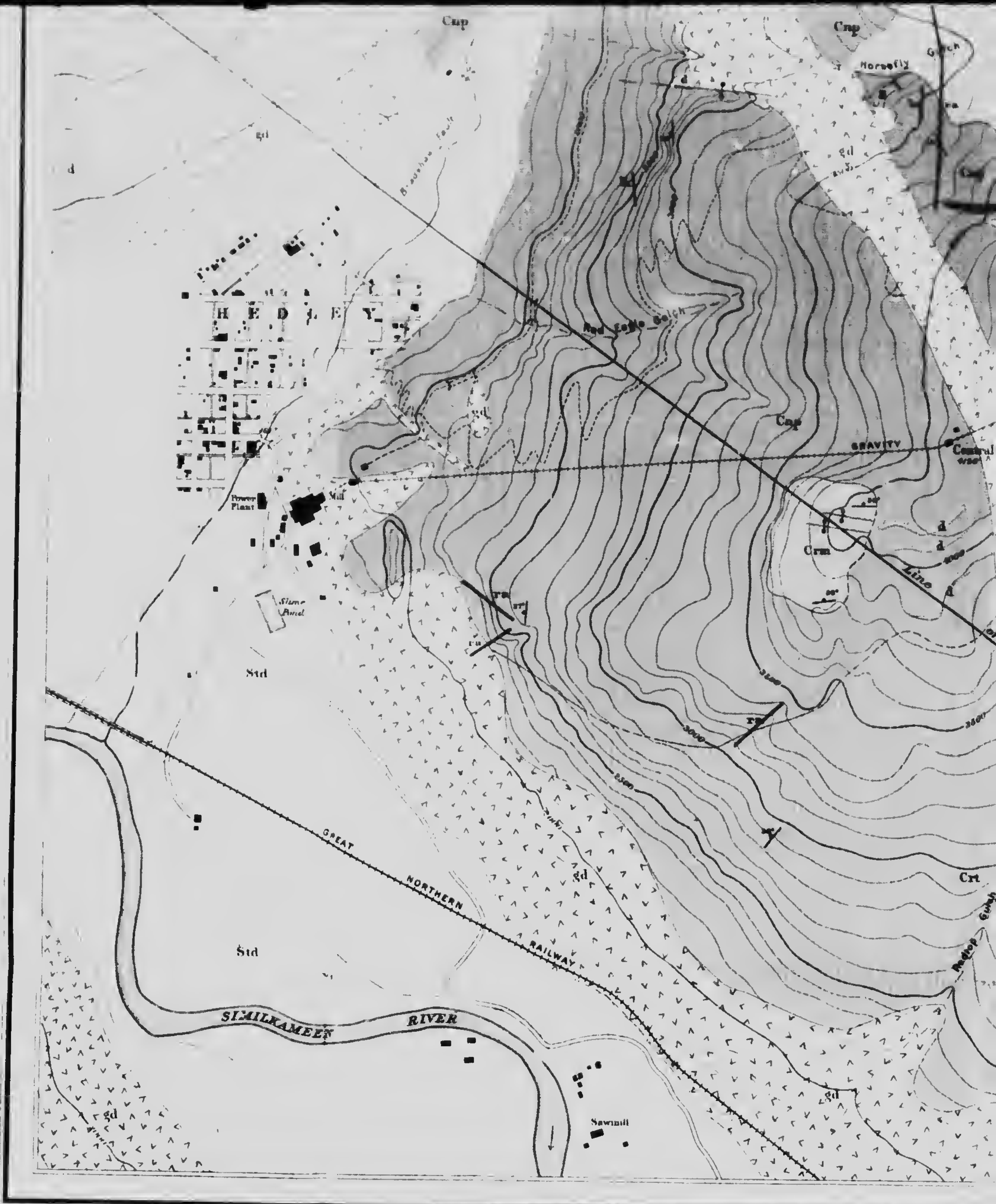
Dip and strike

Geological boundary
delineated within an error of 50 feet

Geological boundary
delineated within an error of 100 feet

Geological boundary
assumed

Note: *Innumerable dikes and small irregular masses of gabbro and diorite are present in various areas but are not shown on the map*



C.O. Senecal, *Geographer and Chief Draughtsman.*
O.E. Prud'homme *and* A. Dickison, *Draughtsmen.*

Scale 30 miles to 1 inch

MAP

HEDLEY MININ

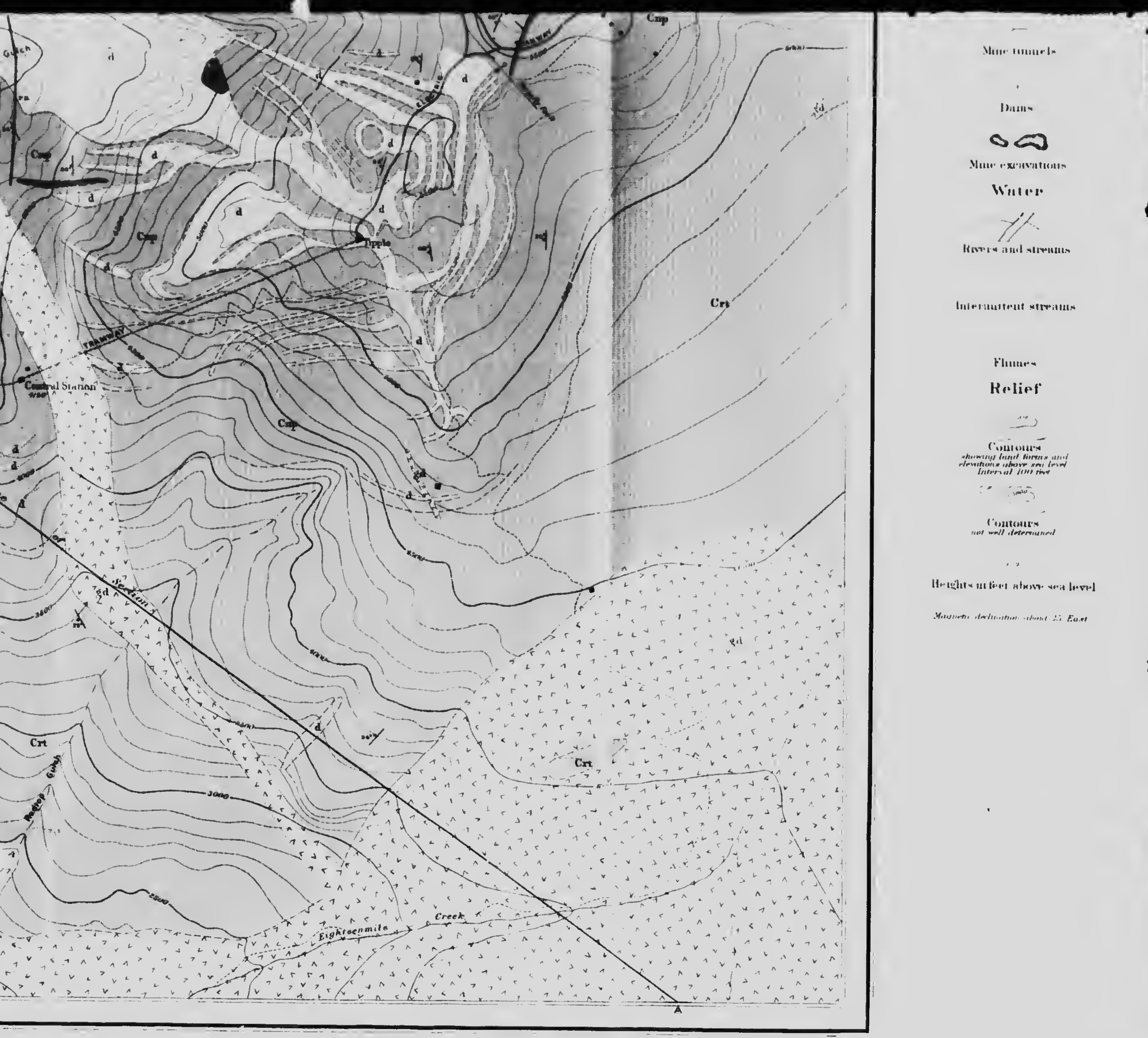
BRITISH C

Scale

Feet

Metres

1000 FEET T



MAP 2 A

MINING DISTRICT
SH COLUMBIA

Scale $\frac{1}{12000}$

Feet

Metres

OO FEET TO 1 INCH

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L. REINECKE. 1908

To accompany Memoir No 2.

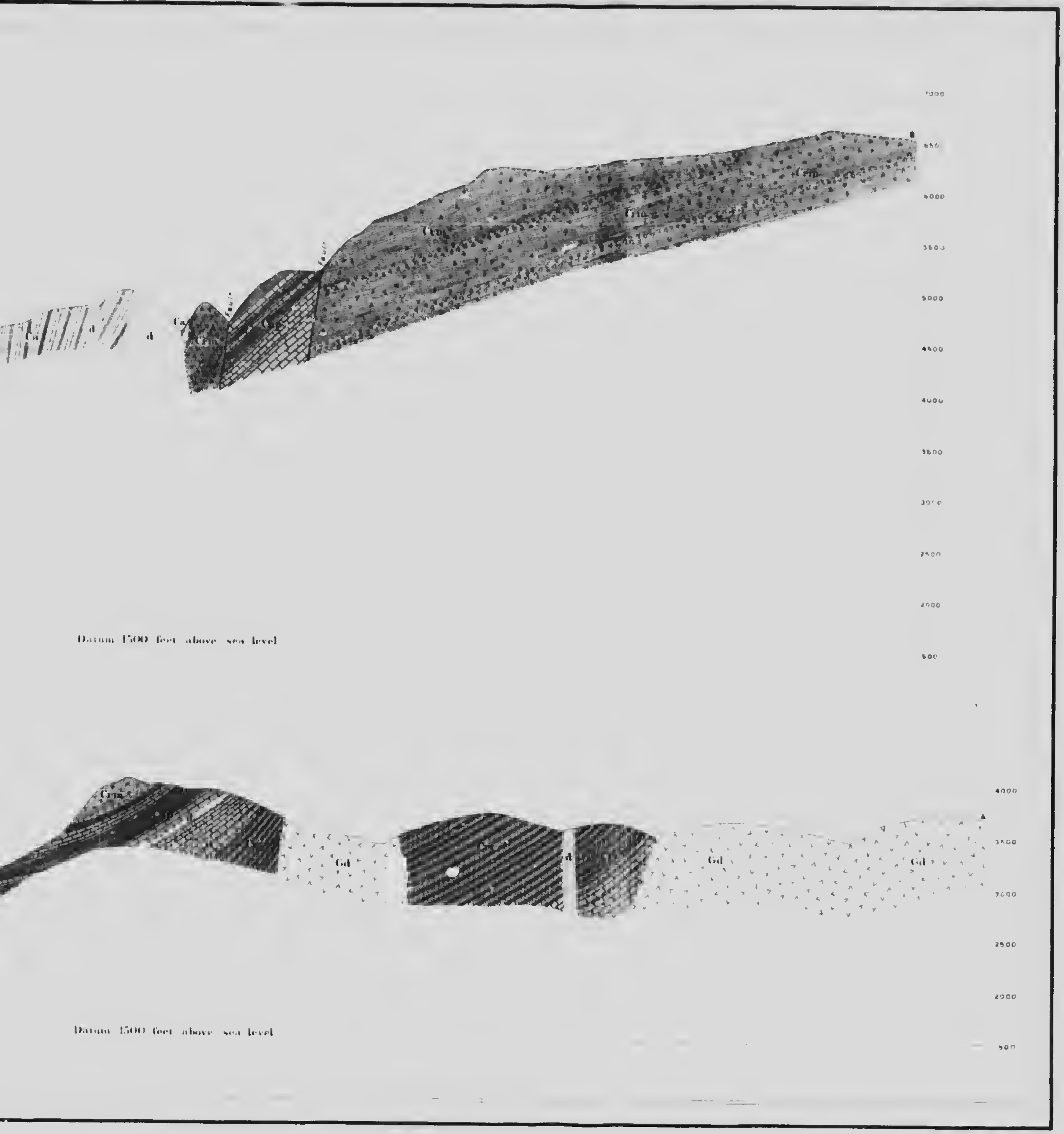

Hon W Te
LEGEND
Sedimentary rocks
Std
Superficial deposits
Ca
Aberdeen formation
Crm
Red Mountain formation
Cnp
Nickel Plate formation
Crt
Redtop formation
Igneous rocks
gd
Granodiorite
d
Diorite
PALAEOZOIC
CARBONIFEROUS
MESOZOIC TERTIARY
RECENT
4500
3500
3000
2500
2000
4000
1500
Ca
Cr
d
gd
Std
STRU
HEC

Canada
Department of Mines
GEOLOGICAL SURVEY

Hon W Templeman Minister A P Low Deputy Minister
R W Brock Director

1910

BRITISH COLUMBIA



STRUCTURE SECTIONS

to accompany Map 2A

HEDLEY MINING DISTRICT B C

Scale $\frac{1}{12000}$

1000 FEET TO 1 INCH

GEOLOGY

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Ca
Departmen
GEOLOGIC

Hon W Templeman, Minis
R W Broc

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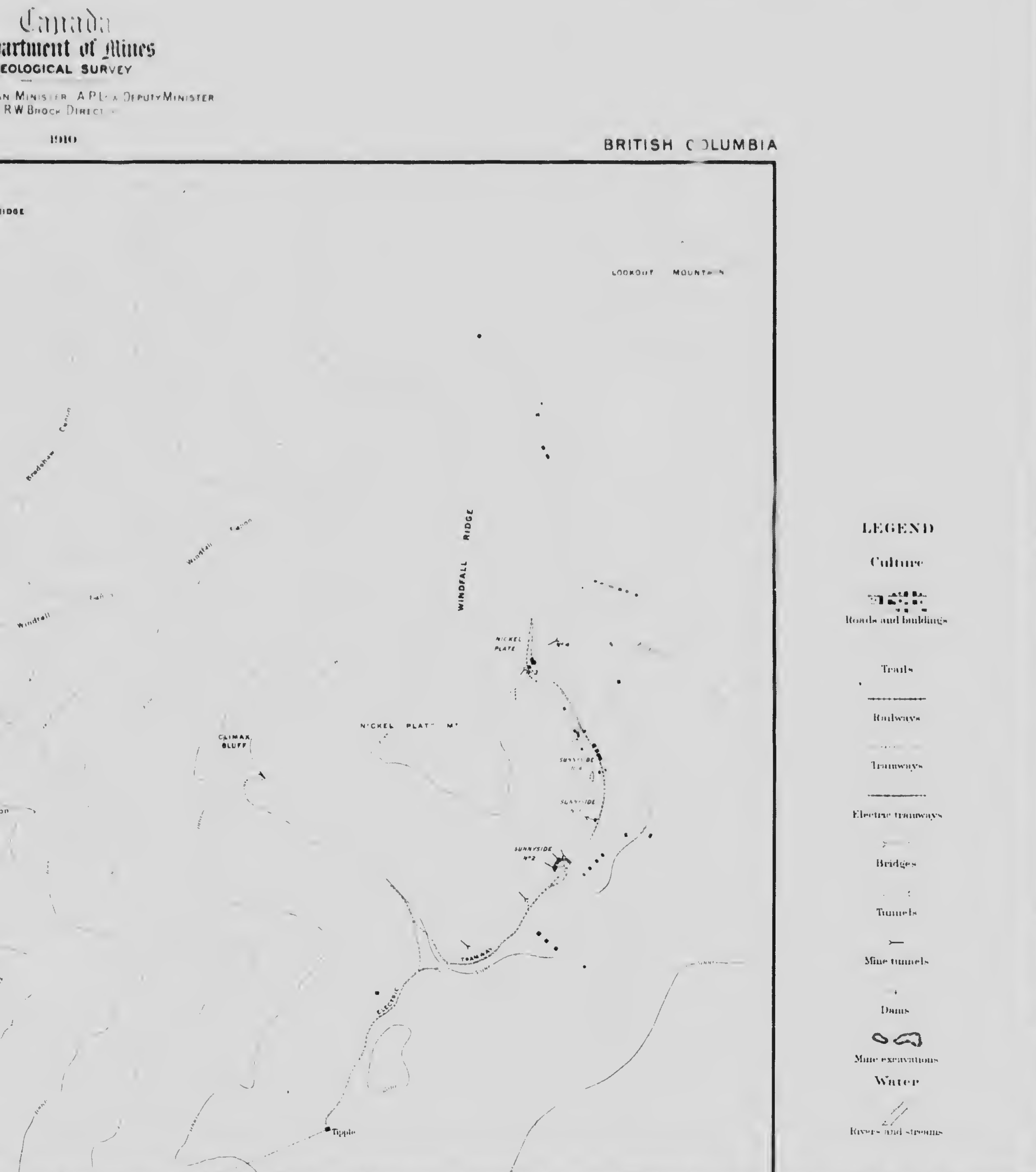
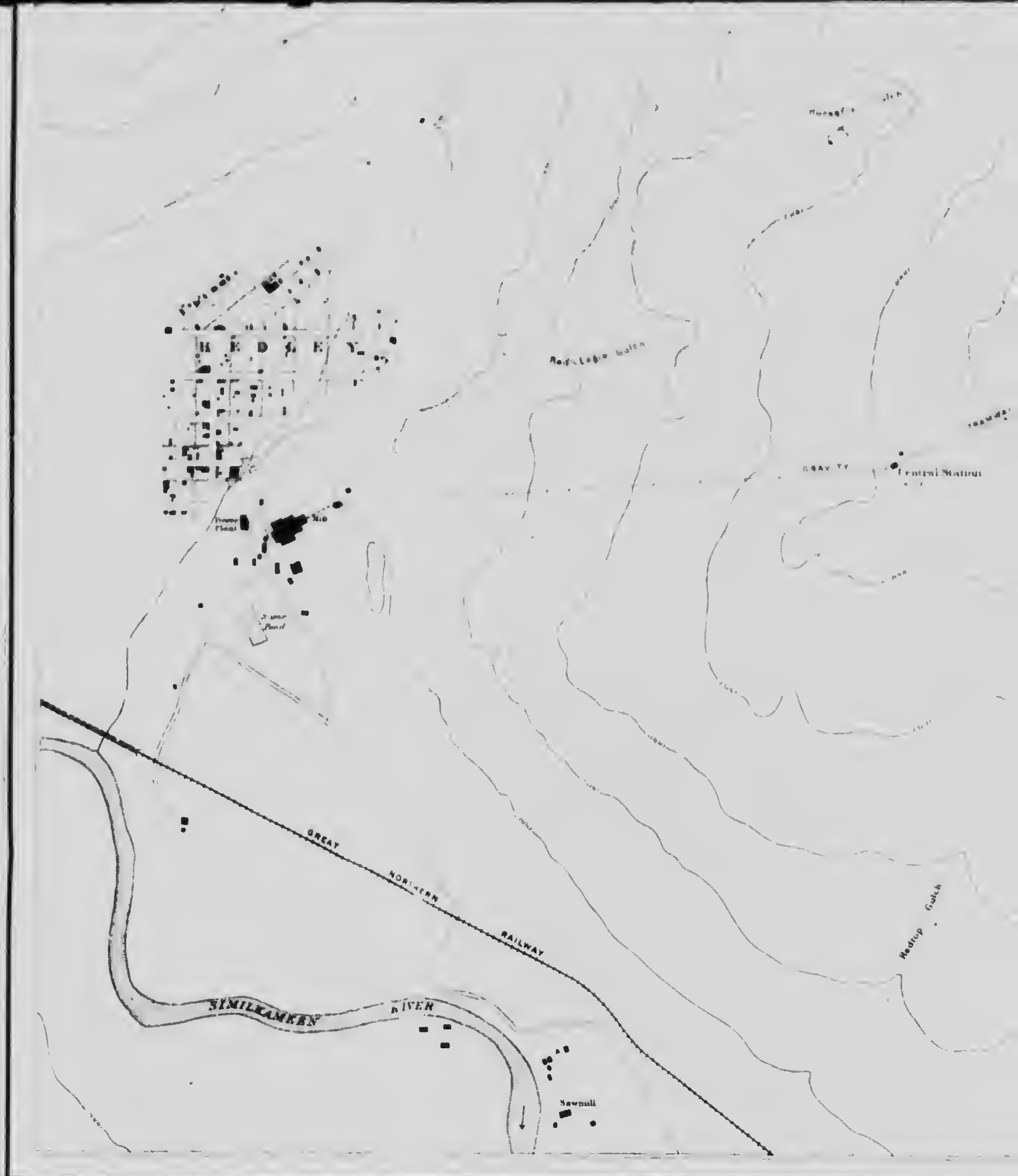
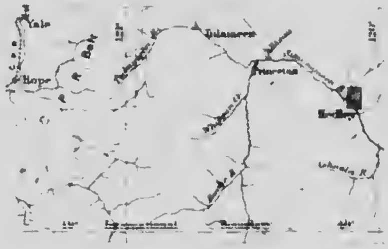

Canada
...artment of Mines
...EOLOGICAL SURVEY
1910
BRITISH COLUMBIA
LOOKOUT MOUNTAIN
WINDFALL RIDGE
NICKEL PLATE
NICKEL PLATE MT
CLIMAX BLUFF
SUNNYSIDE
SUNNYSIDE Nº2
TRAMWAY
ELECTRIC
Tipple
Windfall
LEGEND
Culture
Roads and buildings
Trails
Railways
Tramways
Electric tramways
Bridges
Tunnels
Mine tunnels
Dams
Mine excavations
Water
Rivers and streams
Intermittent streams



C.O. Senecal, Geographer and Chief Draughtsman
O.E. Prudhomme and A. Dickison, Draughtsmen



Scale 30 miles to 1 inch

MAP 1A

HEDLEY MINING DI

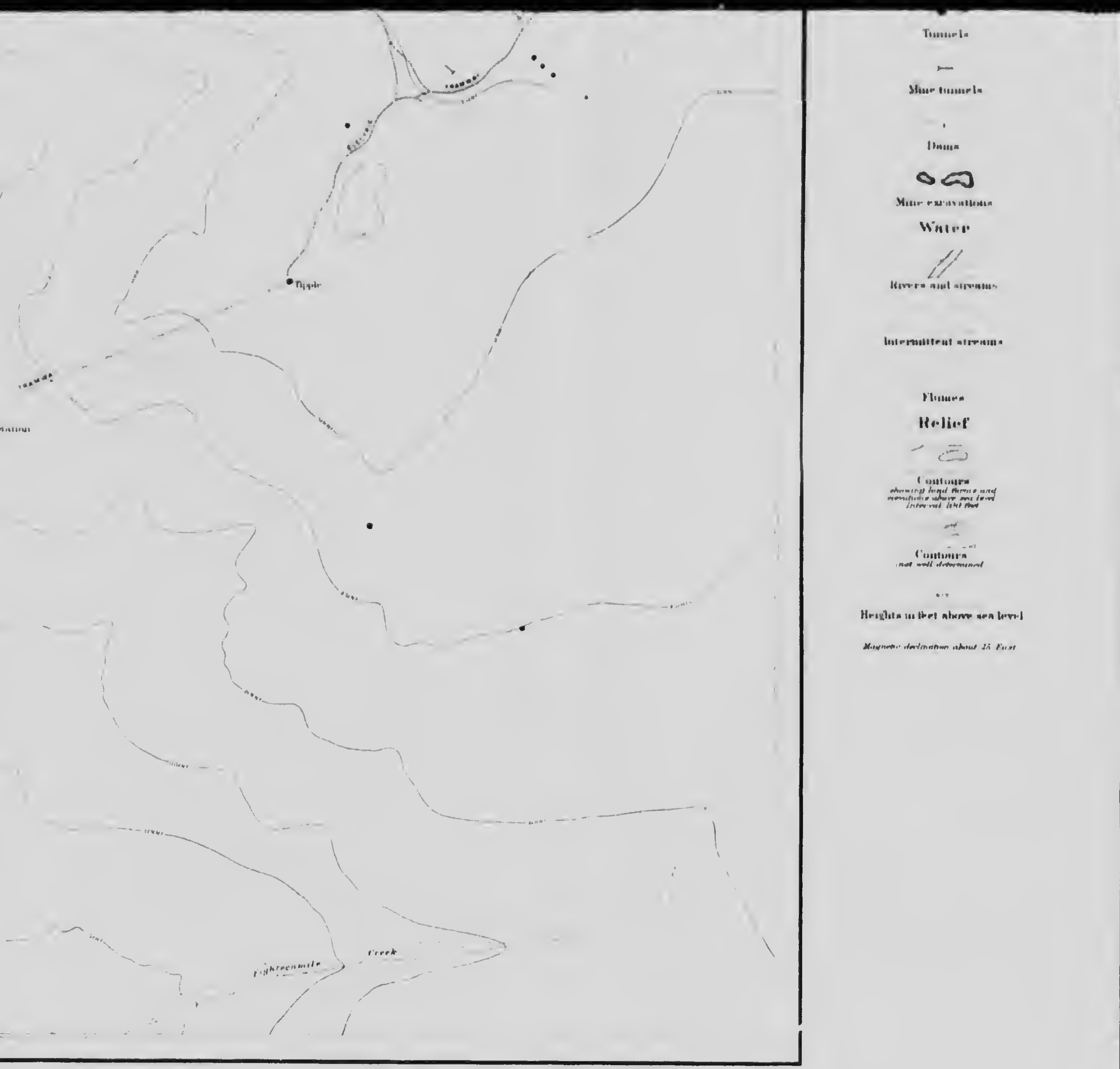
BRITISH COLUMB

Scale : $\frac{1}{12000}$

Feet

Metres

1000 FEET TO 1 INCH



IA

G DISTRICT

OLUMBIA

$\frac{1}{12000}$

1 INCH

TOPOGRAPHY
(subject to revision)

C. CAMSELL, (IN CHARGE)	1907-1908
L. REINECKE.	1908

To accompany Memoir Nº 2